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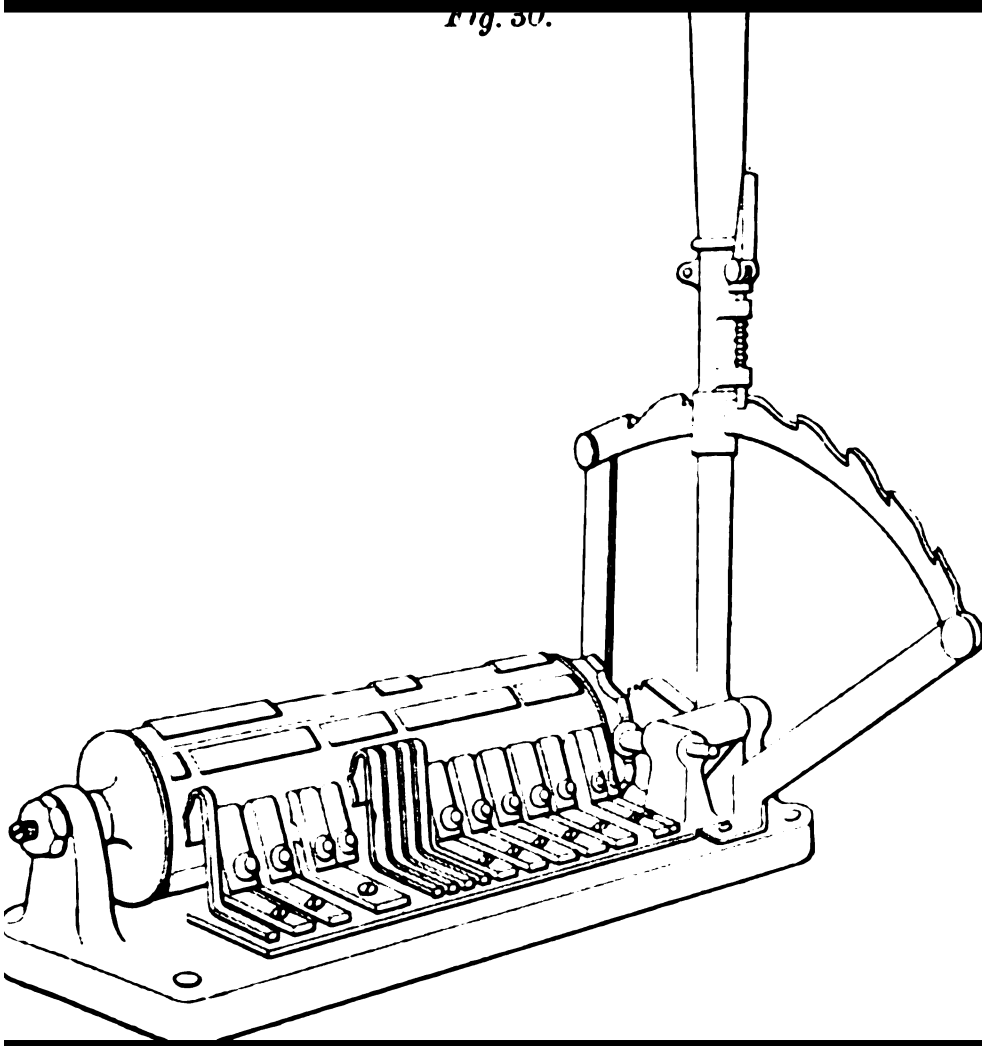

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MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CLII.

EDITED BY

J. H. T. TUDSBERY, D.Sc., M. INST. C.E., SECRETARY.

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CONTENTS.

Sect. I.—MINUTES OF PROCEEDINGS.

13 and 20 *January*, 1903.

	PAGE
Transfer of Associate Members to the class of Members	1
Admission of Students	1
Election of Members and Associate Members	2
"Electric Automobiles." H. F. Joel. (23 cuts)	2
Appendix to ditto. (1 cut)	33
Discussion on ditto. (1 cut)	40
Correspondence on ditto	64

27 *January* and 3 *February*, 1903.

"The Nile Reservoir, Assuan." M. Fitzmaurice. (2 plates and 2 cuts)	71
Appendix to ditto	107
"Sluices and Lock-Gates of the Nile Reservoir, Assuan." F. W. S. Stokes. (2 plates and 3 cuts)	108
Discussion on the two preceding Papers	124
Correspondence on ditto	140
Announcement of the death of Sir George Gabriel Stokes, Bart., Honorary Member	155
Transfer of Associate Members to the class of Members	156
Admission of Students	156
Election of Members and Associate Members	156

Sect. II.—OTHER SELECTED PAPERS.

"The Construction of the Lu-Pao District of the Lu-Han Railway. T. J. Bourne. (11 cuts)	157
Appendix to ditto	184
"Erection of the Nairne Viaducts, near Adelaide, South Australia." W. E. Cook. (1 plate)	185

Digitized by Google

PAGE

"Dry Dock at Riley's Hill on the Richmond River, New South Wales." A. D. CRAIG. (4 cuts) 188

"The Düsseldorf Navigation Congress, 1902; and Works visited by the Congress in Germany." L. F. VERNON-HARCOURT. (2 plates and 5 cuts) 196

"Burraga Dam and Water-Supply for the Lloyd Copper Company's Mines, New South Wales." J. H. CARDEW. (4 cuts) 237

"Notes upon Municipal Work in Sydney, New South Wales." R. W. RICHARDS 251

"Recent Developments of the Asphalt Industry." W. H. DELANO . . 258

"The Cauvery Power-Transmission Scheme." H. T. HINCKS 269

"Notes on the Construction of the Permanent Way of Electric Tramways." R. BRUCE. (18 cuts) 285

Appendix to ditto 309

Obituary 312

Field-Marshal Sir John Lintorn Arabin Simmons, 312; John Addison, 315; Thomas Morrison Barr, 317; Walthew Clarance Barton, 318; David Wilkinson Campbell, 319; George Edward Gavey, 320; Nathanael Robert Griffith, 322; Edward Beversham Hanson, 322; Charles La Fletcher Hillman, 323; Charles Le Lievre, 324; Godfrey Oates Mann, 325; Francis Carr Marshall, 326; Robert Augustus Oldham, 328; Charles Robins, 330; Martin Samuelson, 331; Joseph Miller Wilson, 332; John Steddy Winbolt, 336; Arthur Ernest Baldwin, 336; William Aitken Duff, 337; Thomas Montague Howden, 338; John Macnie, 338; Henry James Castle, 339; Abram Stevens Hewitt, 340; George Braithwaite Lloyd, 343.

Recent Deceases 344

SECT. III.—ABSTRACTS OF PAPERS IN SCIENTIFIC TRANSACTIONS AND PERIODICALS.

The Bex-Gryon-Villars, and Aigle-Leysin Mountain Railways, Switzerland. K. A. BREÜER 345

Fall of the Roof of the Cornallaz Tunnel at Chexbres (Switzerland) . . 346

The Gellivare Northern Railway 346

Locomotives and Rolling Stock on the Eastern Railway of France. L. SALOMON 347

New Passenger-Carriages. C. P. SCHÄFER 350

Treadles for Single-line Railway 351

Economical Speed of Goods Trains. R. GOSTKOWSKI 352

Tests of Locomotive Performance. VON BORRIES 352

Digitized by Google

PAGE

Lubrication with Graphite for Locomotives. Bruck 353
Electric-Accumulator Traction on Heavy Railways. Mühlmann . . . 354
Lock-and-Block Signalling with no Releasing-Key. O. Walzel . . . 355
Point-lock with Electric Release. J. Schnatter 355
Rolling Platforms for Extension of Wayside Stations. L. de Nys . . . 356
The Bremgarten-Dietikon Electric Street-Railway 357
Lattice-Girder Bridges, with Flexible Connections. R. Bonnin . . . 357
Staircase with Right and Left Treads 358
Use of Caissons with Compressed Air for Extending River-Piers . . . 359
25-Ton Floating Crane for the Works of the Port of Ceuta 359
Heating-value of Superheated Steam. C. Bach 360
Strength of Cylinder-Supports of Vertical Engines. G. Schwarz . . . 360
High-Speed Pumps. Lecuir 361
The Production of Power by Means of Small Motors. F. de Boor . . 363
Design of Internal-Combustion Motors. H. Güldner 363
Gas-Engine Research. E. Meyer 364
Heat-Balance of Gas-Engines. A. Staus 366
Three-cylinder Compound Gas-Engine 366
On the Phenomena of Combustion in Stationary Alcohol Motors. Sorel . 367
A New Tachymeter. Puller 368
Manufacture of Peat Charcoal. J. J. Tylvad 369
Asphalt Refining. W. R. Crane 371
Mica Mining in India. T. H. Holland 372
Pendulum-Propeller Trials. H. C. Vogt 372
Cavitation. J. A. Normand 373
Further Experiments with Ozone for Water-purification. Proskauer and Schüder 375
Hamburg Waterworks. R. Schröder 375
Water-tank with Hemispherical Bottom at Washington Heights, Chicago. 376
A New Method of Heating Buildings. H. Fischer 377
The Paris Cold-storage Depôt. D. Bellet 378
Strength of Tall Chimneys. Preuss and Lang 378
A Water-Power Electricity Station at Burgos (Spain) 379
The Water and Electrical Power System of the Pike's Peak Power Company, Colorado. W. P. Hardesty 380
Variable-Speed Polyphase and Direct-Current Motors. Dr. Behn-Eschenburg 381
150-HP. Polyphase-direct Rotary Transformer 382
Changes in the Construction of German Telephone-Cables 383
Telephone Cable-Conduits with Single Ways. Rühl 383
Siemens and Halske's Improvements in Telephone Exchanges. Dankwardt 384
Strength of Struts. A. Ostenfeld 385

Digitized by Google

PAGE
Testing Hard Lead. F. W. Küster, P. Siedler and A. Thiel . . . 386
The Plasticity of Clays. B. Zschokke 386
The Permeability of Mortars. H. Le Chatelier 388
The Portland-Cement Industry. E. Candlot 388
The Conversion of Blast-furnace Slag into Iron-Portland Cement. Jantzen 389
The Tensile Strength and Deflection of Ferro-concrete Constructions. F. Schule 391
Dry-Rot. Malenkovic 392
Hydraulic Laboratory of the Technical High School at Karlsruhe. T. Rehbock 393
Construction of Thermometers. Steinle 395
Alternate-Current Electrolysis. E. Wilson 396
Pulverized Fuel for Power Plants. F. G. Gasche 397
Stability of Automobiles on Curves. A. Petot 397
The Zossen-Marienfelde Polyphase Railway Trials 398
High-Speed Electric Railways. G. W. Meyer 399
Competition of Steam and Electric Railways. C. H. Davis 400
Electric Railways. L. Gerard 400
The Diatto Surface-Contact System. C. H. Julius 401
The Transition Spiral. W. M. Torrance 401
Electric Locomotive for Rack and Adhesion Railway. M. Gaze . . . 402
Tractive Effort and Power of Tramway Motors. H. C. King 402
Telephone Conduits. Rühl 403
Transit Theodolite for Mining Engineers. H. D. Hoskold 403
Harmet Process for the Production of Steel Direct from the Ore . . . 403
The Parallel Operation of Alternators. H. E. Longwell 404
Chenard-Walcker Motor Carriage 405
Ader Light Automobile. L. Fournier 406
Daimler Cars 407
Barton's Airship 407
Standardizing Electrical Machinery 408
Electrically Operated Plant on the North Sea Canal 409
The Fayet-Chamonix Electric Railway 410
Train Resistance. W. J. Davis, Jr. 411
Electro-Pneumatic Railway System. B. J. Arnold 412
Relative Cost of Steam and Electric Railway Operation. B. J. Arnold . 414
Determination of Grades and Alignment 415
Torsional Stress in the Connection between the Ship's Engines and the Propeller. H. Frahm 416
Tests of Steam-pipe Coverings. G. H. Barrus 416
Liquid-Fuel Combustion. C. E. Lucke 417
Insulated Lines in India. K. A. Scott-Monorieff 418
Soulanges Canal Electric Plant 418

Digitized by Google

PAGE
Water-power in Ireland. W. Tatlow 420
The Edison Company's Station, Boston. L. E. Moultrop and R. E. Curtis 420
Concord N. H. Water-power Plant 421
Brakes for Tramcars. C. J. Spencer 423
Tests of Steam Turbine at Hartford, Conn. W. L. Robb 423
The Garbage Furnaces of Trenton 423
Gola's Lightning-Arresters 425
Electricity in Iron- and Steelworks. F. Kylberg 426
Electrical Power in the Iron and Steel Industries. D. Selby-Bigge . . 427
Effect of Closed Slots in Stator Cores of Induction Motors. W. Mollier . 427
Protection of Electric Transmission Lines against Lightning. Dussaugey 427
Detroit, Ypsilanti, Ann Arbor and Jackson Railway. F. E. Merrill . 428
Detroit United Railway Power-Stations. T. Farmer 429
Electrical Equipment of the Consolidated California and Virginia Mining Company, Nevada. L. M. Hall 430
Index 431

CORRIGENDA.

Vol. cli. p. 75, line 3 from bottom, *for* "0·000018" *read* "0·0000018."
,, ,, p. 76, line 10 from bottom, *for* "day" *read* "clay."
,, ,, p. 192, footnote to Table, *for* "(p. 51)" *read* "(p. 191)."

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THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1902–1903.—PART II.

SECT. I.—MINUTES OF PROCEEDINGS.

13 January, 1903.

JOHN CLARKE HAWKSHAW, M.A., President, in the Chair.

It was announced that the Associate Members hereunder mentioned had been transferred to the class of

Members.

THOMAS MACKENZIE BATCHEN.
WALTER BESSLEY.
AUGUSTUS WILLIAM HARVEY BELLINGHAM.
RICHARD EVANS WILLOUGHBY BERRINGTON.
JOHN HENRY CLEMES.
EDWARD ALEXANDER CULLEN.
ALBERT DENISON.
CLAUDE FRANCIS ARTHUR EGERTON.
THEODORE GRAHAM GRIBBLE.
JOHN FREDERICK HARRISON.
KENNETH PHIPSON HAWKSLEY.
HUGH TORRANCE KER.
CHARLES RAMSDEN MAY.
WALTER MAY.
HARRY BERTRAM NICHOLS.
MARTYN FENWICK DE PLEDGE.
JOHN PRYDE.
HENRY REEVE, C.M.G.
ALEXANDER CRAIG RENTON.
FREDERICK WILFRID SCOTT STOKES.
WILLIAM JAMES TAYLOR.
CYRUS JOHN RICHARD WILLIAMS.
GEORGE WINSTANLEY.

And that the following Candidates had been admitted as

Students.

GEORGE JAMIESON ALLEN.
FRANCIS BACON, Jun.
JOHN ALFRED BAKER.
LUCIUS AVELING BAKER.
WILLIAM JOHNSON CLARKE.
CHARLES GEOFFREY COTTON.
WILLIAM ROBERT DAVIDSON.
IVOR PARRY DAVIES.
ST. JOHN ALEXANDER DAVIES.
CHARLES SHERBORNE DODSON.
HERBERT OSBOURNE HAGGAR ETHERIDGE.
GEORGE PURDON GEEN.
WILLIAM ROWATT HORN.
WILLIAM REES JENKINS.
ROBERT MENZIES MACGREGOR.
ARNOLD STEWART MASON.
FREDERICK WALCOTT FRANKLAND MOSER.
LÉON MAXIME RAMPAL.
LOUIS FRANÇOIS RAMPAL.
FRANK WILLIAM CRAMER ROBERTS.
CHARLES WILLIAM SHAW.
RICHARD EMRYS THOMAS.
CYRIL SPENCER WILSON.

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The Candidates balloted for and duly elected were: as

Members.

JOHN HARDISTY.
FREDERICK WILLIAM KITE.
GEORGE HENDERSON MACKAIL.
TOM HUGH GODDARD ROGERS.
JOHN WILLCOCKS.
ERNEST SEYMOUR WOOD.

Associate Members.

BERTRAM KEITH ADAMS.
HAROLD GWYNNE ALLEN, B.A. (*Cantab.*)
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CHARLES JOHNSTON, Stud. Inst. C.E.
EVELYN LLEWELLYN HUSTLER JONES.
WILLIAM GREGORY KRAY, Stud. Inst. C.E.
ALBERT NORMAN RAMSEY.
RICHARD EAGLE REEVES.
THEODORE RICH, Stud. Inst. C.E.
EDWARD MARSHALL ROSHER.
JOSEPH SHEPHERD.
CYRIL TURNER WALKER, B.Sc. (*Edin.*)
JAMES WATT, Stud. Inst. C.E.

(*Paper No. 3336.*)

"Electric Automobiles."

By HENRY FRANCIS JOEL, Assoc. M. Inst. C.E.

AT the present time there are, in London alone, upwards of 16,000 licensed horse-carriages, apart from private vehicles, tradesmen's vans, etc. It is estimated that more than 200,000 horses are stabled each night in London, necessitating the daily removal of at least 5,000 tons of manure and refuse, in addition to what is distributed over the roads or finds its way into the residences of the people. The daily growth of London and of other large cities renders the problem of substituting motor-cars for horse-traction, even from a sanitary point of view alone, of the first importance. Motor-cars possess further advantages in point of economy and convenience to the public; and the Author desires to offer to the consideration of the Institution one kind of motor-car, possibly the most practical and certainly the most interesting of all kinds, namely, the electric automobile.

Electric automobiles have now become thoroughly practical vehicles, having satisfactorily accomplished single journeys of more than 100 miles on one charge and tours of more than 1,000 miles (from London to Glasgow and back). Electrical energy is an economical and readily-applied form of power, which is noiseless in its application, gives rise to neither smell nor refuse, and possesses the advantage that it can be turned on and off at

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will. It has also features, such as braking-power and recuperation of energy, which are not possessed by other kinds of motive power.

In order to deal with the question of the most suitable electric car, or the problem of the best means of utilizing electrical energy for propelling vehicles on common roads, it is necessary that the earlier experiences with various kinds of car should be referred to. These have been tabulated as far as possible, and restricted to the essential features of the historical side of the subject. It is only since the passing of the Locomotives on Highways Act, 1896, that the problem of motor-cars has been seriously attacked in England; and this country is far behind France, America, and Germany, where no such restrictions had to be fought against as hampered their development here before 1896. From information obtained officially by the American consul (at the request of a firm of carriage-builders in America, made through the United States Government) it has been ascertained that, in the consular district of Paris alone, there are over 30,000 automobiles—petrol, steam, and electric—in daily use; and the value of motor-vehicles annually exported from France alone is now more than £300,000, and is increasing. In America electric carriages were being made in 1894, and the *Chicago Times-Herald* organized trials of such carriages in November, 1895. At that time the limit of a run on one charge was 20 miles; and apparently only two electric cars competed, as against six gasoline cars. In a more recent automobile show in New York, held in November, 1900, there were seventy electric carriages competing against seventy-three steam-carriages and eighty-one gasoline (petrol) carriages. Germany, France, Austria, America, Italy, Spain, Belgium, and other countries, are giving earnest attention to the manufacture and improvement of electric vehicles; and in most of these countries makers are assisted directly by government subsidies, by official trials as in Berlin, and otherwise. In England it has been left entirely to private enterprise to compete with the foreigner for a share in this new and important industry, which even now gives employment to about 10,000 men in this country.

The weight of the earlier electric carriages was out of all proportion to the weight of the batteries carried by them, as is shown by the examples in Table I. of the Appendix. This was due to the attempt to utilize existing coach-builders' work, strengthened to carry the batteries. One of the most serious defects was the use of wheels of small diameter, especially in heavy vehicles such as omnibuses—a practice which experience has shown to be highly detrimental. Further, the batteries and motors were inefficient, the

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current was wasted in magnetic clutches, and power was lost in complicated worm- and tooth-gearing. Such defects as these explain some of the earlier failures. One instance is recorded of an omnibus that was tried on muddy macadam roads in London. Its total weight was more than 4 tons, of which the battery, stated to consist of seventy cells weighing 23 lbs. each, accounted for 1,610 lbs., or about 18 per cent. of the total weight. The wheels were of small diameter (24 to 30 inches), and the necessary tractive effort under the circumstances must have been about 200 lbs. per ton, which would require 12 HP.; entailing a discharge of about 100 amperes from batteries whose normal rate was probably only 20 amperes. It is not surprising that the omnibus stuck in the mud, and the batteries were destroyed. In the electric cabs used in London a year or two ago, the total weight of the vehicle, battery, motor and gear, for carrying a useful load of 4 cwt. (passengers and driver), was over 2 tons, a ratio of 1:10. These vehicles may be contrasted with a bicycle, weighing only 26 lbs. and carrying 140 lbs., or more than five times its own weight. In the electric cabs the weight on each wheel was about 10 cwt.; in a bicycle the weight on each wheel is about $\frac{3}{4}$ cwt. The life of the bicycle tires is about 5,000 miles, whereas the wear and tear on the rubber tires in the heavier motor-cabs reduced their life to about one-tenth of this.[1]

Table II. of the Appendix shows the rapid progress made during the 5 years 1896–1901 in the use of electricity for propelling carriages on roads.

Table III. of the Appendix gives recent examples of long-distance runs of electric carriages propelled by one charge; and these records are analyzed for comparison. The elevation and plan of some of the carriages are shown to scale, and the arrangement of the batteries is indicated; and as all these cars were specially designed, and not merely adapted, they are instructive as examples. The only entirely English vehicle among them is the Joel electric voiturette (No. 3, Table III.). On a journey from Brighton to London, it was propelled up Handcross Hill, which has a gradient varying between 1 in 20 and 1 in 10, at a speed of 6 miles per hour, and required an average of 109 amperes at 30 volts, or 4·2 E.HP. (more than double the normal power used on the level road at 12 miles per hour), and 3·4 kilowatts per ton of total weight. When going down Handcross Hill, on the out-

[1] Recent trials of pneumatic tires by the Automobile Club of Great Britain and Ireland have demonstrated that tires for motor-cars can now be obtained which will last for more than 4,000 miles.

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ward journey, it returned into the battery 30 amperes to 35 amperes; it is the only car which utilized the kinetic energy of descent in recharging the batteries. The British and Foreign Vehicle Company's car (No. 4, Table III.), on a recent tour in Scotland, ascended the hill at Lennoxtown, 3 miles in length and having an average gradient of 1 in 19·1, taking 80 amperes at 100 volts, or 10·7 E.HP., and 5 kilowatts per ton of total weight. These two examples show the margin in power required when designing such cars. The data in the first four examples in Table III. are reliable as results obtained on ordinary roads, under normal good conditions, and form a useful basis. Example No. 5 is a run round and round one level tract of good road, at a low speed; it was a trial specially made in order to obtain a long-distance record, namely, 187½ miles on one charge. With this object two batteries were carried, and were used alternately; but had only one battery been carried at one time, the total distance that could have been covered would have been 237·9 miles, namely, 142·5 miles with one battery, and 95·4 miles with the other. Carrying a spare battery is therefore not an economical method of using electricity for propelling carriages. The run of No. 3 carriage from London to Brighton is perhaps the severest test of all, requiring an average of 140 watt-hours per ton-mile on the journey, at an average speed of 10 miles per hour; while only 86 watt-hours per ton-mile is required on the level at a speed of 12 miles per hour. The results shown by Table III. indicate the great advance made in electric automobiles, and prove them to afford a practical, reliable and economical mode of transport. ; In Table IV. are collected the results of some official trials of electric carriages, made in France under government supervision, and in America by the *Electrical World and Engineer* of New York. The American trials are highly interesting, and attention is particularly drawn to Nos. 7 and 8. In No. 7, with ball-bearings in axles and motors, the vehicle ran at a speed of 9·85 miles per hour, taking only 88 watts per ton-mile; while in No. 8, without ball-bearings, running at a speed of 8·83 miles per hour, 106 watt-hours per ton-mile were required, showing an apparent advantage from ball-bearings of 25·6 per cent. The American trials Nos. 11, 12 and 13 are also instructive: the "draw-bar pull" is given in the last column; and by calculation of the actual electrical energy expended and the work done, the efficiency of the whole carriage can be obtained. It comes out at 0·65—a high figure, considering the state of knowledge of the subject at that time.

The quantity now accepted as a measure of the efficiency is "watt-

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hours per ton-mile," and as it takes into account the electrical energy consumed, the time, the mass moved, and the distance, it is satisfactory as a guide; but in comparing one car with another, the conditions of running should be as nearly as possible identical.

Storage-Batteries.

The storage-batteries or accumulators used in electric automobiles are adaptations of the storage-batteries used for electric lighting, but are much lighter and give a greater output, weight for weight; they are also made to bear over-discharge, and the wear and tear of rough travelling. The active agents in general use are lead and dilute sulphuric acid. The storage batteries may be divided broadly into two classes: namely, the "to-be-formed," or Planté kind (1873); and the "pasted," or formed Faure kind (1881). The object of both processes is to produce a couple consisting of a positive electrode of lead oxide, and a negative electrode of lead in a solution of sulphuric acid and water. Peroxide of lead is formed on the positive, and pure lead on the negative, by the process of charging; and energy is stored which is given up on discharging the battery, when the electrodes return to their first state of lead sulphate. The pasted cell is lighter than the other, and is more generally used in electric automobiles.

The chief improvements made in storage-batteries for adapting them to electric automobiles are:—modifications in the mechanical details of the supporting grids, so as to allow full expansion of the paste and to avoid sulphating; the increase of the specific gravity of the electrolyte, from between 1·05 and 1·20 to between 1·15 and 1·30, with consequent decrease of volume and weight, and with increased output; improvements in the chemical composition of the active material, *i.e.*, paste; and the mixing of the paste with inert materials, in order to make it more coherent and porous. As a result, batteries for traction now give, weight for weight, three to four times the output of batteries used for electric lighting. The use of zinc with peroxide of lead gives a higher electromotive force (according to Wheatstone 2·446 volts) than lead and lead peroxide, but necessitates the use of porous pots. Such a battery has the advantage that it can be quickly charged, and the whole energy can be stored in 1 or 2 hours. A zinc and peroxide-of-lead battery of 120 ampere-hours can be charged at 90 amperes for 2 hours, and discharged at 20 amperes to 100 amperes.

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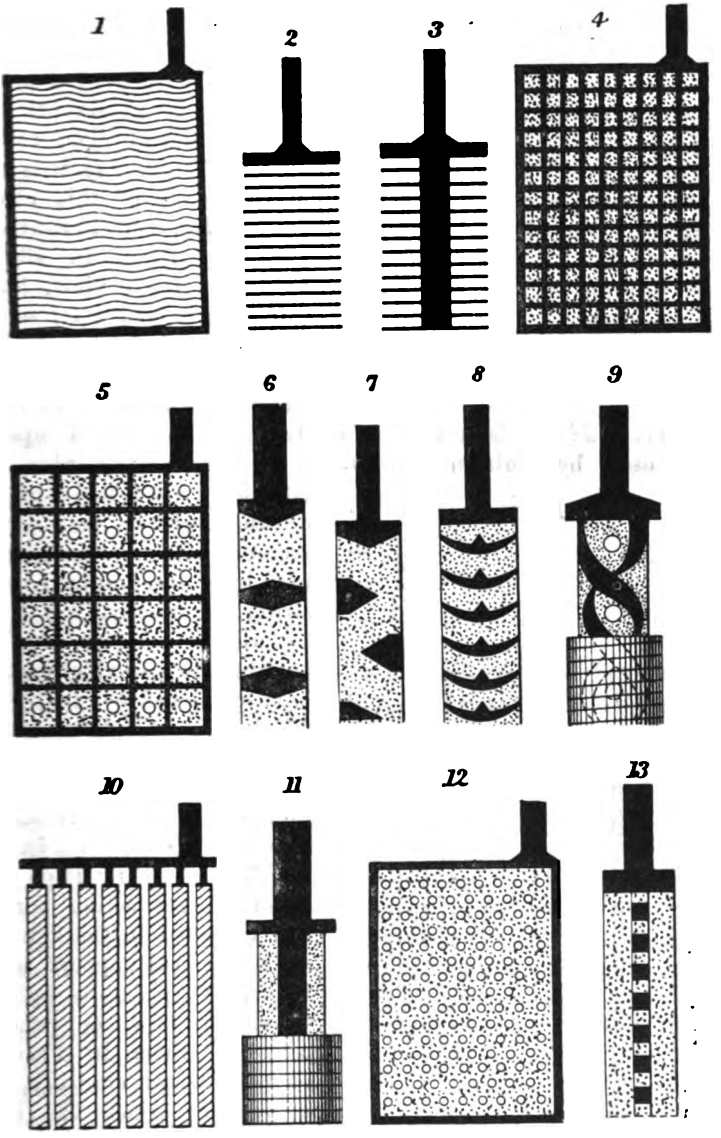
Figs. 1–13.



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Figs. 1–17 show the electrodes of various batteries now in use; the lead is indicated by black, and the active depolarizing paste by dots. *Fig. 1* is a corrugated-lead-strip electrode of Planté pattern, used by De Kabath in 1881, and modified by Tudor and by Blot in France. *Fig. 2* is an enlarged section of this electrode; and *Fig. 3* an alternative proposed by Swan in 1881. *Fig. 4* is a front view, and *Fig. 6* an enlarged section of a pasted-grid electrode, of the Faure-Sellon-Volckmar, or "E. P. S." kind, used in this country. *Fig. 5* is a similar electrode with enlarged openings, used by Fulmen and others in France, and also in America. *Fig. 7* is a section of an electrode for more securely holding the paste, used by Heinz, and by Lindstrum in Germany. *Fig. 8* is a section of an electrode supporting the peroxide paste, used by Humphreys in 1882, and by Majert and others in France in 1900. *Fig. 10* is an electrode formed by a number of the cylinders shown in section in *Fig. 9*, which is used by Pope in America: the active material is pasted in the spirals of the central support, and is kept in place by spiral insulating tape, or bands. *Fig. 11*, known in France as the Phénix electrode, is a cylinder which has the active material placed round a central rod, and kept in position by a pile of ebonite disks which surround it. *Fig. 12* is an electrode formed with a central

Figs. 14.

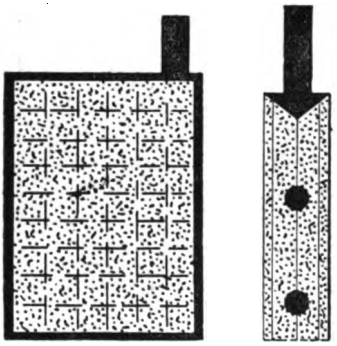

Fig. 15.

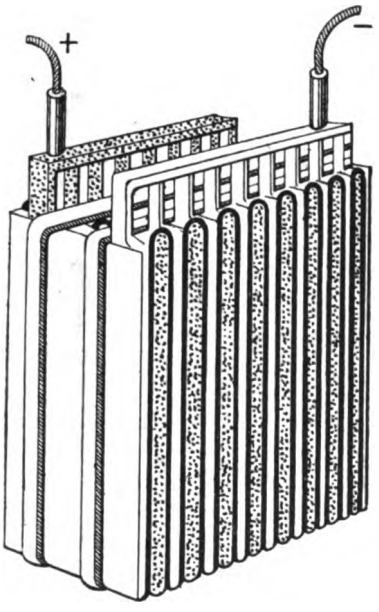

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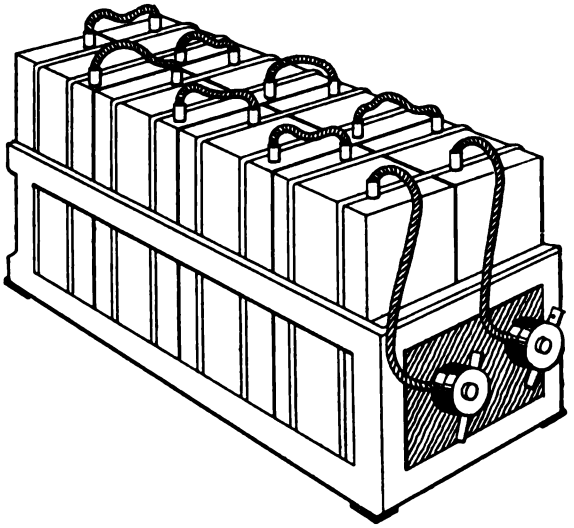
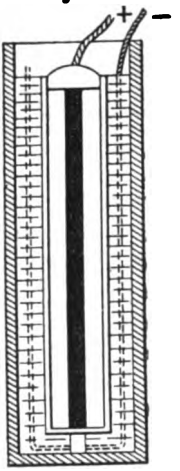
plate of thin sheet lead having perforated, slotted, or punched

Fig. 16.



holes, with the active material entirely covering the conducting plate. It has been used by Somzée, Joel, and Eaton in 1882; Crowdus, Leitner and others in 1899, and is shown enlarged in section in *Fig. 13*. *Figs. 14* show an electrode on which the active material entirely covers the supporting grid (as seen in the enlarged cross section; it has a much larger amount of active material in proportion to the lead conductor than any other kind of cell; it is known in England as the "Rosenthal" or "National" cell. *Fig. 15* shows a battery of "National" electrodes held in position by rubber bands, upon which they rest. The weight of each cell complete is 23½ lbs., and the output is 180 ampere-hours, or 360 watt-hours. The size of cell outside the case is 6⅜ inches by 4 inches by 10 inches high. A group of eight complete cells (*Fig. 16*), arranged in a portable tray for placing in the carriage, weighs 200 lbs., and gives a maximum total of 2,880 watt-hours, equal to 3·86 HP.-hours, or at the rate of 52 lbs. of battery per horse-

Fig. 17.



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power-hour. The dimensions of the tray of eight cells are 33½ inches by 8½ inches by 12 inches high.

Fig. 17 shows a section of a zinc-lead battery having a central rod of lead surrounded by paste held in a porous pot, and an outer electrode of copper gauze chemically coated with zinc, in a solution of zinc sulphate with some cadmium and mercury.

Combinations of the pasted or Faure type for the positive and a formed or Planté type for the negative are used. Majert uses the section shown in *Fig. 3* for the positive electrode, and that in *Fig. 8* for the negative. The Fulmen-Blot battery is a combination of the electrode shown in *Fig. 5* with a modified form of that shown in *Fig. 1*. Pope uses the cylinder shown in *Fig. 11* as the positive, and a modified electrode (*Fig. 14*) as the negative. The best modern practice is to make both plates pasted, but the negative one of thinner section. Particulars of the Edison storage-battery cannot yet be made public. The output of the various storage-batteries, given by the manufacturers, is as follows:—

Battery.	Watt-hours per Lb. of Complete Cell.	E.M.F. of Discharge.
		Volts.
Faure-Sellon-Volckmar	9·0	2·0
Fulmen	11·0	2·0
B. G. S. Modified Fulmen	12·65	2·0
E. P. S. Faure-King	8·0	2·0
Rosenthal "National" cell	15·0	2·0
Lee-Coll. (Lead and zinc with cadmium)	10·6	2·5

Some careful tests to determine the durability of storage-batteries were made by the Automobile Club of France in 1899, extending over 6 months.[1] They were made under conditions analogous to those that would obtain in the carriages in actual use. The sets of batteries were equally charged with 24 amperes at 2·5 volts per cell, but were discharged at rates varying between 20 amperes and 100 amperes, with intermediate periods of rest; and while being discharged they were subjected to artificial vibration, in order to give the effect of the vibration occurring

[1] *L'Électricien* (Paris), 2nd series, vol. xix. p. 20.

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on roads. This treatment was continued until the cells showed signs of failure. The results were as follows:—

BATTERY-TESTS MADE BY THE AUTOMOBILE CLUB OF FRANCE, 1899.

Name.	Electrodes.		Weight. Lbs.	Total Number of Discharges.	Total Kilo-watt-Hours.	Ton-Miles at 100 Watt-Hrs. per Ton-Mile.	Efficiency fell from	Total Kilo-watt-Hrs. per Lb. of Cell.	Cubic Feet of Space required by Battery.
	+	−					Per Cent.		
Tudor .	Formed	Pasted	236·5	135	135·8	1,358	67 to 60	0·57	2·2
Fulmen Blot .	„	„	215·6	132	143·9	1,439	76 „ 68	0·67	2·0
Fulmen.	Pasted	„	148·5	98	101·9	1,019	77 „ 66	0·67	1·36
Phénix .	„	„	202·4	102	118·8	1,188	75 „ 66	0·5	2·01
Pope .	„	„	220·0	135	155·5	1,555	74 „ 70	0·7	3·0

The highest output was obtained with the Pope battery, which gave an output equal to running 1,555 ton-miles with 4 per cent. loss of efficiency, but occupied a large space. The pasted Fulmen cell has flat electrodes (*Fig. 5*), occupies little room, and gives a high output; on this account it is almost universally used in France.

Recent tests of storage-batteries in America and in England have shown much better results; and in France 3,000 ton-miles is at present obtained with about 10 per cent. loss of efficiency. Storage-batteries for electric automobiles can be obtained which will give 1 HP.-hour for 67·2 lbs. weight of complete cells, with a durability of 3,000 ton-miles, allowing 10 per cent. loss of efficiency, and an efficiency of charge and discharge of 80 per cent. This means that an electric vehicle, weighing, say, 6 cwt., with a battery weighing 6 cwt. and a load of the same amount, could run 10 miles per day for 330 days in the year, *i.e.*, 3,000 ton-miles, taking 100 watt-hours per ton-mile, with 10 per cent. loss of efficiency in the battery.

ELECTRIC MOTORS AND GEARS.

The motors designed specially for electric automobiles are of light weight compared with electric motors used for driving stationary machinery, and are of high efficiency: they are capable of bearing very rough usage, and an overload of 100 per cent.

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for short periods. The necessity of meeting such conditions has acted as an incentive to the improvement of this class of motor. The following is a brief account of the motors now in use on electric carriages.

Fig. 18.

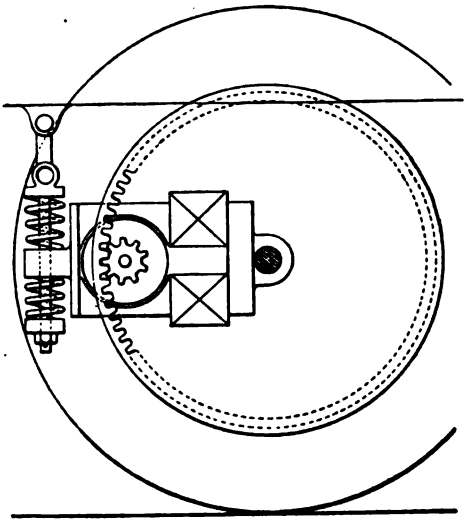
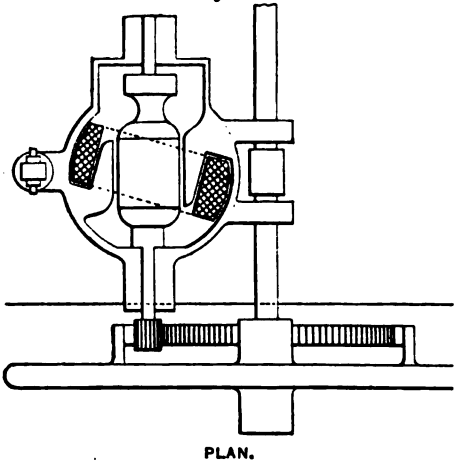


Fig. 18 is a side view of a well-known type of two-pole electric motor and driving-gear, much used for electric automobiles. The motor is pivoted at one end on the carriage-axle, while the other end is suspended from the carriage between two spiral springs on a jointed hanging rod. The springs allow movement up or down, as required by the movement of the carriage; and they also serve to diminish the sudden strain of starting, due to the inertia of the carriage, when the current is sent through the motor. The armature has a pinion at its end, gearing into an internally toothed ring attached to the spokes of the carriage-wheel. *Fig. 19* is a plan of this gear, but with a bipolar single-coil Lundell motor, extensively used in America.

Fig. 19.



PLAN.

Fig. 20 is a side view of the motor and suspension introduced by Kriéger, of France, and used in the Kriéger electric automo-

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biles (Table III., No. 6). Two motors are used, each of which is geared by a pinion to a toothed ring attached directly to one of the two front wheels. The motor is of the four-pole type, completely encased. It is suspended on an arm pivoted to the axle of the carriage-wheels; and is further supported by a strong plate-spring fixed to the axle, having at the outer end a connecting link attached to the other side of the motor-casing. This spring allows movement in the same way as do the spiral springs in the motor shown by *Fig. 18*.

Fig. 20.

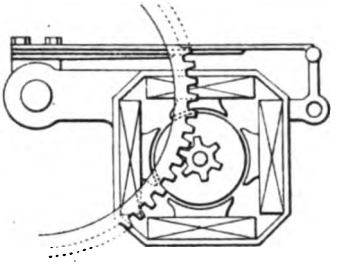
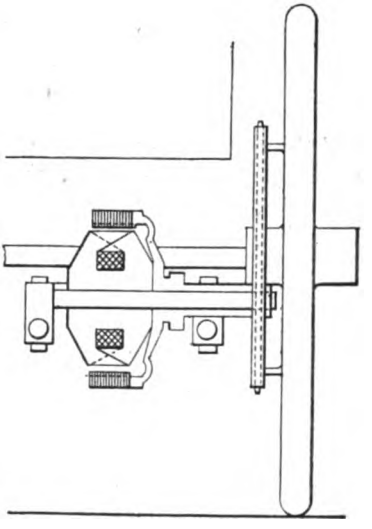


Fig. 21 is a section, and *Fig. 22* the side elevation, of an arrangement of electric motors designed by the Author. The motors are supported on a flexible tubular underframe, independent of the body of the carriage. They are eight-pole motors with the armatures revolving outside the fields, differing in this respect from other motors. The armature has a long sleeve-bearing with a sprocket-pinion at its end, which by means of a chain drives the large sprocket-wheel attached to the spokes of the carriage-wheel. The chain can be adjusted by means of the screwed pin and lock-nuts fixed at the end of the supporting tube. The motor is light, weighing 112 lbs. and giving 2 B.HP. at 700 revolutions per minute. It runs sparklessly; and owing to the large surface of wire exposed on the armature it will stand an overload of 100 per cent., while it has an efficiency varying between 80 per cent. and 90 per cent., according to the load. In the Author's experience these motors have run for 6 months at a time without inspection or any other attention than oiling the bearings.

Fig. 21.



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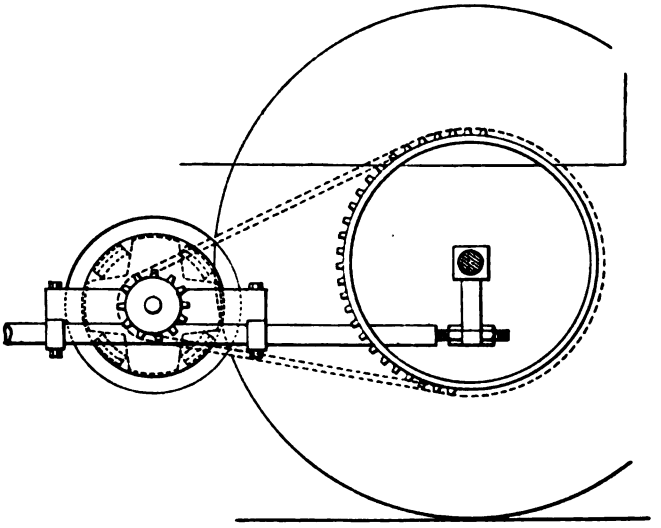
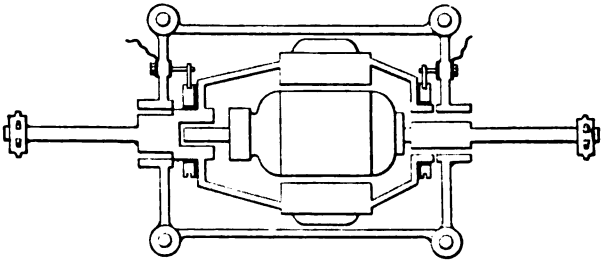
In *Fig. 23* is shown a double-acting electric motor, adapted by Still in Canada for driving automobiles. The armature revolves in one direction, driving a sprocket-pinion on one side;

Fig. 22.



and the field-magnets revolve in the opposite direction, driving a separate sprocket-wheel on the other side. The whole motor is supported in a casing on four spiral springs attached to the under-

Fig 23.



side of the carriage. The double action has some advantages: the speed of the armature is reduced, and the two carriage-wheels are driven independently without the necessity of a differential

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gear; but extra bearings are required (ball-bearings are used to obviate additional friction), and additional rubbing-connections must be used to convey the current. The advantages of a double-acting motor do not, in the Author's opinion, compensate for the simplicity of a single motor with differential gear, or two motors directly acting on each wheel independently.

Electric motors are used by Monnard having two armatures, driving independently, with one field-magnet in common. The Bouquet, Garcin and Schivre Company employ two armatures, one or both being used according to the power required. Motors with the revolving armature fixed directly to the carriage-axle have been tried, but their weight is prohibitive. Motors fixed in the hubs of the wheels, with toothed-wheel reducing-gears, are used in Austria; but in the Author's opinion they are not reliable. Motors driving vertically by means of bevel-gear fixed to the front axle are also used. Worm-gearing, introduced by the late Mr. A. Reckenzaun, is often used; but it has the disadvantages of increased frictional loss, and difficulty of moving the carriage by manual labour when cleaning. Numerous modifications of motors and gears have been tried, but those referred to are in practical use.

Controllers and Circuits.

Many ingenious methods have been devised for controlling electric automobiles in regard to direction of travel, speed, braking, recuperation and recharging. The controller is simply a commutating switch, or circuit-changer; and the system in general use is an adaptation of the series-parallel controller used on electric railways and tram-cars. It consists in grouping the batteries in parallel or in series, as change of speed is required; or in grouping the motors in parallel or in series with the same object; and also in combining the two.

Figs. 24 and *25* show the system used by Jeantaud, of Paris. For "low speed forward" two batteries in parallel are in circuit with a single compound-wound electric motor (*Fig. 24*). For the third speed forward the connections are altered, and the batteries are in series (*Fig. 26*).

Figs. 26–29 show the circuits used by Kriéger in the car No. 4 of Table III., with two compound-wound electric motors. In *Fig. 26* ("low speed forward") the batteries are in parallel and the motors in series. In *Fig. 27* the batteries are in series, giving a higher speed to the motors and carriage. In *Fig. 28* the field-

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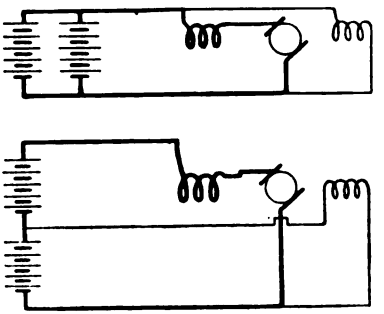
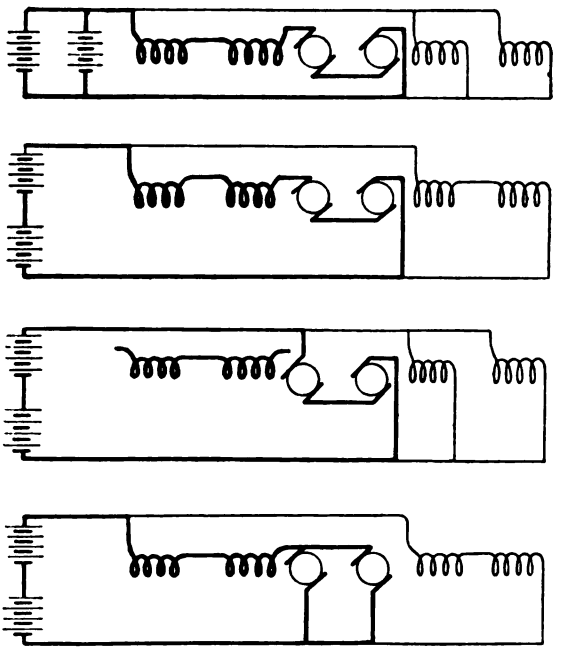
magnets are weakened by cutting out the series field-coils, with a

Figs. 24 and 25.



JEANTAUD SYSTEM OF SPEED-REGULATION.

Figs. 26–29.



KRIÉGER SYSTEM OF SPEED-REGULATION.

further increase of speed; in this position they become shunt-

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wound only; and when run at a speed higher than their normal speed as motors, say when going down a steep hill, they act as

Fig. 30.

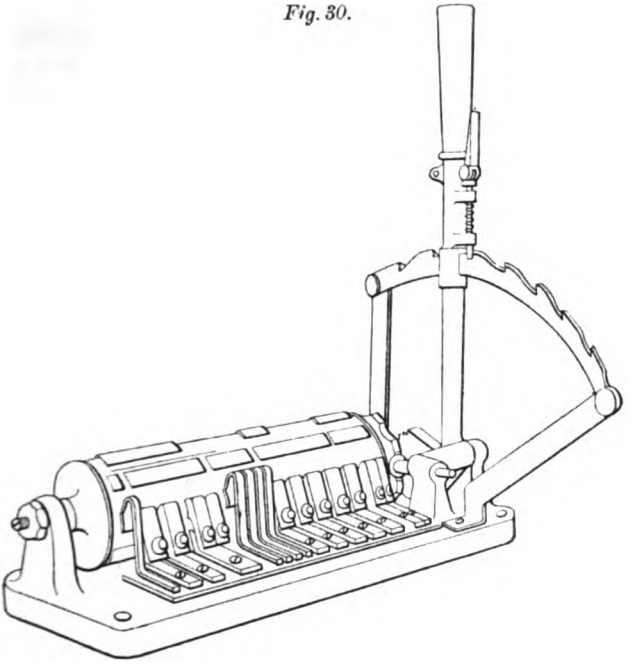
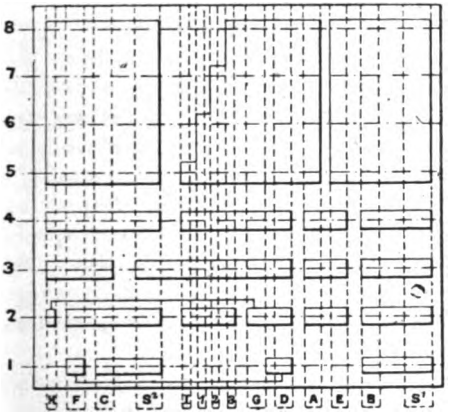


Fig. 31.



dynamos, and give a back or recuperative charge to the batteries, and also act as a brake upon the carriage. In *Fig. 29*, the reverse of

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Fig. 26, the batteries are in series and the motors in parallel, to give the maximum power at high speed. These two methods exemplify virtually all the principles of regulation, but there are many varieties in the details of their practical application.

A complete controller is shown in *Fig. 30*, and is a fair example of all of them. It consists of a cylinder of insulating material, having longitudinal strips and plates of metal fixed round its surface in a certain order, while a number of insulated contact-arms or spring-blades press on the strips and are connected with the batteries and motors. *Fig. 31* is a plan of the cylinder unfolded, to show the position of the strips and plates, and the spring contact-blades in combination therewith. The cylinder is turned by the hand-lever into the eight set positions, and the strips and plates on its surface are brought against the spring-blades so as to make the following combinations, shown in the diagrams of the circuits (*Figs. 32*).

(1) The two batteries are joined in series for recharging, the motors being cut out.

(2) Low speed back: field-coils reversed.

(3) Stop: motors short-circuited act as a brake; batteries cut off.

(4) Low speed forward: motors in series.

(5) Medium speed, 6 miles per hour for hill-climbing: motors in parallel, batteries in parallel; all working at highest efficiency and greatest power.

(6) Higher speed, 8 miles per hour: resistance in field-coils.

(7) 10 miles per hour: additional resistance in field-coils.

(8) 12 miles per hour: all resistance in field-coils: motors over-run at double normal speed of No. 5.

The plan is briefly as follows:—On the basis that the greatest power is required for hill-climbing, the speed is made suitable as in No. 5, and the maximum discharge from the battery is kept within a pre-arranged limit. For running on level roads at higher speeds the motors are over-run; and for slow running they are connected in series. A most interesting feature of this plan is the use of shunt-motors only, and the consequent recuperation, or back charge given to the batteries, when the speed of the motors exceeds the normal and they act as dynamos. Also, whenever the carriage is stopped, the momentum returns some current to the batteries.

In the Northey system, used in the Electromotive Force Company's carriages, the batteries are grouped in different combinations, *e.g.*, with forty cells, four groups of ten in parallel, or two groups of twenty in parallel, or all forty in series. This

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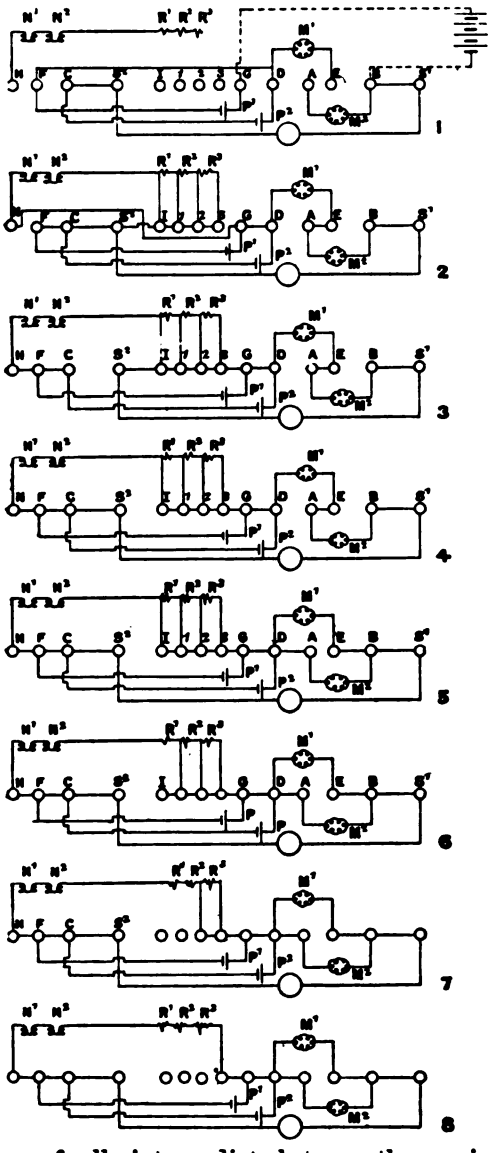
is the simplest form of control, the changes being made by

Figs. 32.



joining groups of cells, intermediate between the required changes, so that there may not be any breaks in the circuits.

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Underframes.

The arrangement and the construction of the underframe of the carriage to carry the motor and batteries as well as the carriage body, present several points of interest. Examples of underframes are given in *Figs. 33–39*.

Fig. 33.

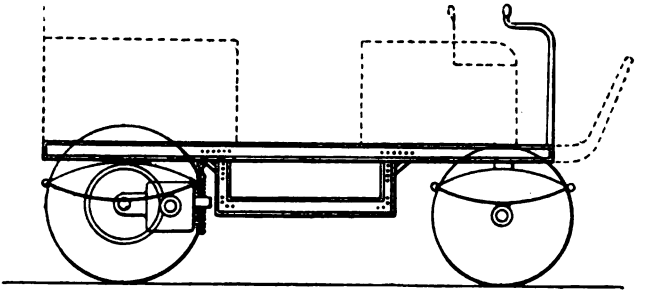
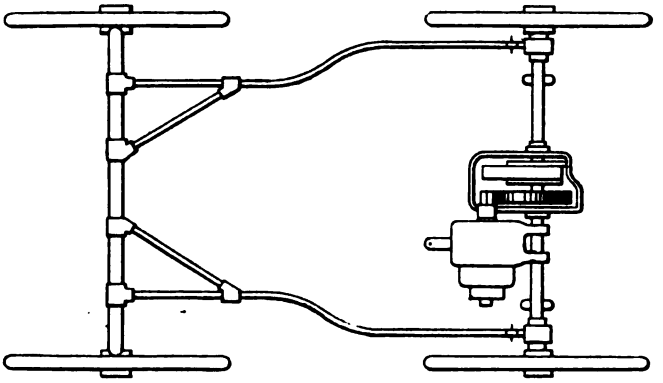


Fig. 33 shows the simplest form of construction of an electric goods lorry. The rectangular underframe is made of channel steel, and the battery is supported or suspended in a receptacle

Fig. 34.



under the platform. The two electric motors are geared to the back wheels, as in *Fig. 18*. This form of lorry is used by Messrs. Altman and Company, of New York, for their heavy goods service, and will carry a load of 2 tons. *Fig. 34* is an underframe

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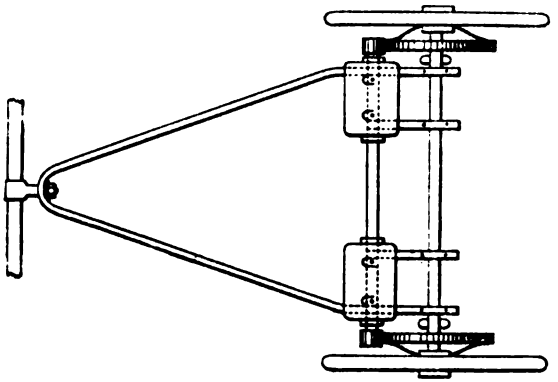
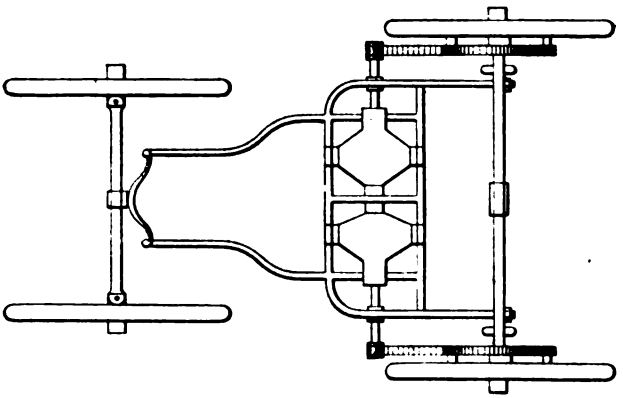
used by Riker and made of steel tubes. A single electric motor drives the carriage through toothed gearing and a balance gear with a live axle. *Fig. 35* is the Scheele underframe, made of

Fig. 35.



sectional steel, and carrying two electric motors, geared as shown to the two back wheels. *Fig. 36* is a plan and *Fig. 37* an end view of the Joel underframe, of steel tube, carrying two electric

Fig. 36.



motors, which drive the two back wheels by bicycle chains (*Figs. 21* and *22*). The frame is supported by a half elliptical carriage-spring placed horizontally and pivoted to the centre of the front axle; and by a half elliptical spring placed vertically, and

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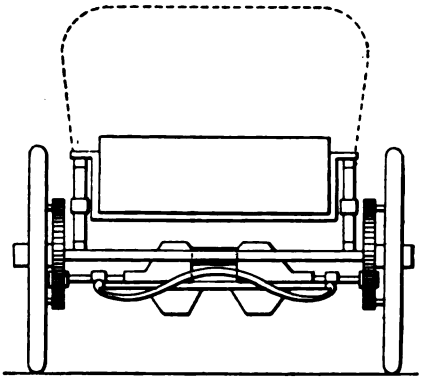
secured to the centre of the back axle. These two springs allow a resilient movement both horizontally and vertically. While the chains are adjustable and are kept in proper tension by the front spring, the back spring takes up the strain of starting the carriage.

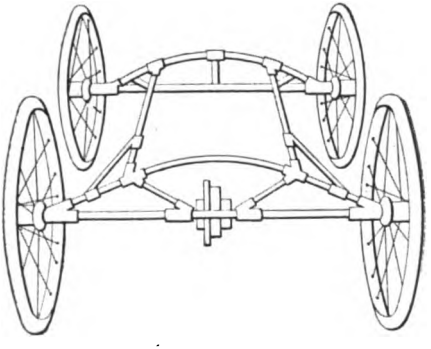
Fig. 37.



The two motors lift when the current is put on, and thus supply additional energy to assist the carriage in starting. The batteries are placed under the seats of the carriage.

Figs. 38 and *39* show American steel tubular under-frames. This

Fig. 38.



kind of frame is both light and strong, and is specially designed to support the motors and batteries independently of the carriage-body. The illustrations show two excellent examples, and more nearly approximate to modern bicycle-construction than any of the

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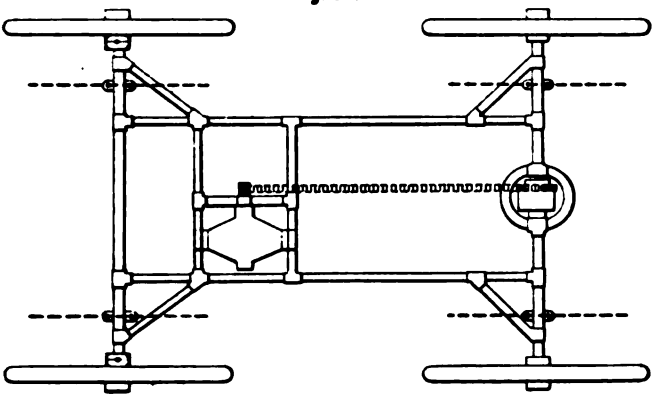
others. Such a frame is used in the "Runabout," No. 5 of Table III. (Appendix), which holds the record for long distances.

One of the objects of these underframes, *Figs. 34–39*, is to form a "perch pole" or "reach," coupling the back to the front axle, so

Fig. 39.



that the two are propelled together, and the power has not to be transmitted indirectly through the carriage-springs, as in *Fig. 33* it has to be.

In these examples the front wheels are pivoted at the ends of the front axles, on what is known as the Ackermann principle, so as to enable them to turn for steering.

Design and Construction.

The arrangement of the batteries, so as to equalize the weight over the front and the back wheels, and the shape of the carriage in relation to air-resistance, are important.

Wheels.—The size of wheels has recently received special attention. Dr. Luxenberg has shown [1] that on level roads the resistance to traction, and the energy consumed, are, within certain limits, inversely proportional to the diameter of the wheels of the car; and he advises the use of wheels between 3 feet 3 inches and 5 feet, or more, in diameter. He estimates that the adoption of these larger wheels, in place of the 2-foot 6-inch or 3-foot wheels generally used, would effect on the level a saving of about 40 per cent.; but this would not apply to hill-climbing, for

[1] *Centralblatt für Accumulatoren und Elementenkunde*, vol. i. p. 360

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which the power must be increased almost in proportion to the gradient, necessitating either a lower speed or a large reserve of battery-power. Wheels over 3 feet in diameter present difficulties in regard to reduction of speed. It is obvious that wheels of such diameter bridge the ruts and depressions of a bad road much better than 2-foot wheels; and with the heavy weight of electric cars the sinking and re-lifting of the car means great loss of power. Some tests of the resistance of carts and wagons on common roads were made at Bedford in July, 1874.[1] Carts with wheels 4 feet 6 inches in diameter required a draw-bar pull of 28 lbs. per ton of gross load; wagons with wheels 3 feet 3 inches in diameter required a draw-bar pull of 43·5 lbs. per ton. These forces are approximately in the inverse ratio of the diameters of the wheels.

The difficulty of increasing the diameter of the wheels of self-propelled carriages occurs in the reducing-gear; and the problem is not on parallel lines with that of horse-drawn carriages, because the diameter or the leverage of the driving-chain on the toothed wheel fixed to carriage-wheel or axle has to be taken into consideration, along with the diameter or the leverage of the carriage-wheel.

Solid rubber tires are much used for electric motor-cars: they add to the comfort, and run with less noise than iron tires. Pneumatic tires are preferable, as being more resilient; but they are more expensive than solid rubber tires and not so reliable.

Bearings.—Roller- and ball-bearings are advocated, and minimize friction. As already pointed out, Examples 7 and 8, Table IV., show a saving of 25·6 per cent. due to the use of ball-bearings in the motors and wheels.

Air-resistance.—Assuming that air-resistance follows Smeaton's rule, $p = \frac{V^2}{200}$ (where V is velocity in miles per hour, p is pressure in pounds per square foot), and also that, for purposes of calculation, the irregularities of the surface of a car may be allowed for by regarding the cross-sectional area of the car as forming half the curved surface of a cylinder (on which the pressure will be 0·54 of the pressure on a cross section through the axis of the cylinder), the pressure becomes serious at above 12 miles per hour, and has to be taken into account in determining the power required. The electric motor can be made with as high an efficiency as 85 per cent.; and the loss in the gearing, especially high-class chain-gear, is not more than about 2½ per cent. Allowing 25 per cent. for all

[1] *Engineering*, vol. xviii. p. 23.

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losses, including the friction of the carriage-wheels, 75 per cent. is a fair all-round efficiency, and well within the conditions of practice.

When properly designed, electric automobiles possess the unique feature that they can return energy to the batteries when running downhill, the momentum of the vehicle causing the motor to act then as a generator, while at the same time forming a convenient automatic brake. At the Chislehurst trials[1] in November 1900, the highest current recorded for car No. 3 (Table III.) when ascending the steepest hill (gradient 1 in 10) was 119 amperes, and in descending the same hill a back charge of 35 amperes was given to the battery (*Fig. 40*). The total weight of the car, with passengers, was 19 cwt. The tractive resistance may be taken for rough gravel and macadam roads as 50 lbs. per ton on the level, *i.e.* 47·5 lbs. for this car; then the effective horse-power required to propel the car up an incline of 1 in 10, at a speed of 6 miles per hour, would be 4·2 HP. This corresponds with the actual current observed, namely, 119 amperes at 30 volts to 32 volts, taking the efficiency of the electric motors with connecting wires and contacts at 84 per cent. The additional power required to ascend the gradient of 1 in 10, and included in the 4·2 effective HP. given, is $\frac{W \times V}{m \times 33{,}000}$ horse-power; where V is the speed of the car in feet per minute, W is the total weight of the car in pounds, and the gradient is 1 in m. In this case the required power will be $\frac{W \times V}{10 \times 33{,}000}$ horse-power; and it is evident that, when descending a hill of 1 in 10, a considerable part of this power, less the tractive resistance, is available for recuperating or charging the battery. Allowing 25 per cent. higher speed when going downhill for generating, and taking the efficiency again at 84 per cent., the actual power available is 1·9 HP.; which, at 40 volts, will give 33 to 35 amperes as the return charge to the battery, corresponding with what was observed. The duration of the charging is less, because the speed is increased 25 per cent.; but taking this into account in the example referred to, at the speeds given there would result a return of about 23·5 per cent. of the energy taken when ascending the same hill; and this agrees with numerous observations made on many runs. Of course the speed downhill would be comparatively low—only 7½ miles per hour; but on a hill, say, 3 miles in length,

[1] *Electrical Review*, vol. xlviii. p. 390.

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the current returned would be between 10 ampere-hours and 20

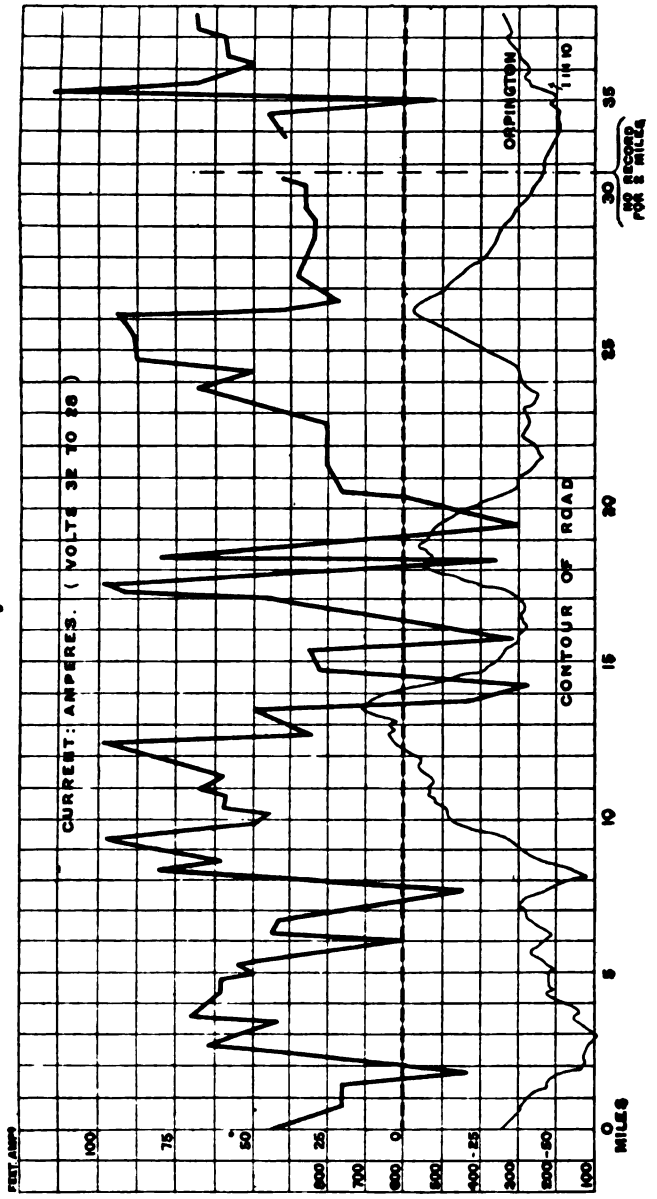

Fig. 40.

ampere-hours, which would be sufficient to propel the car 3 to

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5 miles on good level roads—a gain which might be very convenient at the end of a long day's journey. If the car were sent downhill at 15 miles per hour, it would still give a back charge to the battery, but for only half the time. One direct advantage due to this recuperation is depolarization of the batteries, which restores them to their maximum electromotive force after their heavy discharge when ascending a hill. In many long runs on electric automobiles the Author has not used the mechanical brake at all, stopping and reducing speed solely by the reactive effect of the motor. This renders the control of an electric motor-car simpler than that of any other self-propelled vehicle; and with shunt-wound motors there is no loss of energy in stopping, but rather a gain. An electric carriage which won a prize for quick stopping was stopped in 14 feet 6½ inches from a speed of 10 miles per hour.[1] No horse-drawn carriage could be stopped within twice that distance under like conditions.

Ratio of Power to Load.

The ratio of the weight of the vehicle to the weight of the power-giving battery is of great importance. Generally, as the ratio of the weight of the battery to the weight of the vehicle increases, so the distance that such a vehicle can be run on one charge is increased; but of greater importance from a practical point of view is the load-carrying capacity, and the ratio of the weight of the useful load to the weight of the battery and vehicle. The Author offers the following arguments for consideration, as leading to a solution of the problem of the most economical proportions of these three elements. Taking the efficiency of the motor and gear at 75 per cent., a battery of accumulators weighing 6 cwt. will give an effective power of 10 HP.-hours, or 67·2 lbs. for 1 HP.-hour. Assuming an output of 15 watt-hours for 1 lb. of complete battery, a 6-cwt. battery would convey itself against a tractive resistance of 50 lbs. per ton (or $\frac{1}{45}$) at the rate of 12 miles per hour for a total distance of 250 miles, equal to 75 ton-miles. Assuming that the vehicle to convey this battery would weigh 6 cwt., the distance that could be run with vehicle and battery would be 125 miles, and with a load of

[1] New York Automobile Show, New York, U.S.A.; Riker Electric Carriage. See *The Automotor Journal*, vol. 5, p. 130.

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3 cwt. (driver and passenger) the distance would, under the same conditions, be reduced to 100 miles, with the same ton-mileage throughout. With twice the load, or 6 cwt., the distance of the run would be reduced to 83·8 miles; and with three times the load, namely, 9 cwt., the distance would be further reduced to 71·4 miles, again equal to 75 ton-miles. The cost of carrying the useful load would be—for the 3-cwt. load, at the rate of 0·9*d.* per ton-mile; for the 6-cwt. load, 0·55*d.* per ton-mile; and for the 9-cwt. load, 0·45*d.* per ton-mile. The conclusion is that, as the load is increased, the cost of conveying the useful load per ton-mile is reduced; but although this is so, the limit is soon reached when the vehicle must be made stronger and heavier to carry the increased load, so that the running-cost of the whole is increased, as well as the first cost and the consequent allowance for depreciation and interest.

In order to determine these points, the Author has investigated examples of electric vehicles in the following Table, and has prepared curves (*Fig. 41*) showing the ton-mileage in con-

EXAMPLES OF ELECTRIC CARS.

	Conditions.	1	2	3	4	5
		Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
A	Battery increased by equal units of weight	3	6	9	12	15
	Car increased by equal units	4	6	8	10	12
	Constant load	3	3	3	3	3
	Total	10	15	20	25	30
B	Battery as in group A	3	6	9	12	15
	Car increased equally with battery	3	6	9	12	15
	Load increased equally with battery	3	6	9	12	15
	Total	9	18	27	36	45
C	Battery as in group A	3	6	9	12	15
	Car increased by equal units	6	9	12	15	18
	Load increased equally with car	6	9	12	15	18
	Total	15	24	33	42	51

junction with the ratio of weight of battery to the total weight, the ratio of useful load to total weight, the cost of electric energy per ton-mile of useful load, the cost of energy for propelling the car and battery without load at 12 miles per hour, and the relative weights and costs of cars.

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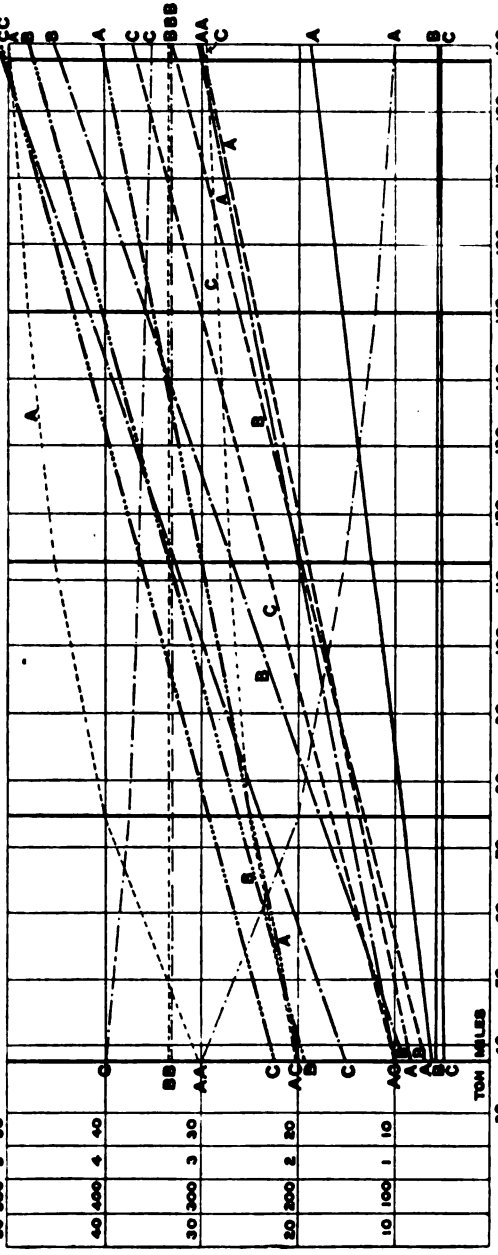
Fig. 41.



A B C.——————*Cost of electric energy per ton-mile for useful load at 1½d. per Board-of-Trade unit, 12 miles per hour.*

" - - - - - - - - - - - - - - *Ratio of weight of battery to total weight (per cent.), and "ton-miles" car can run with battery at 12 miles per hour.*

" —·—·—·—·— *Percentage of useful load.*

" — — — — — *Cost of electric energy in pence for running car with batteries but without load, 12 miles in 1 hour at 1½d. per unit*

" ·····*Cost of complete car in pounds sterling, and proportionate interest on outlay.*

" ——·——·—— *Weight of complete car in hundredweights, and proportionate cost of maintenance.*

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The cost of electric energy is taken at 1½*d.* per Board-of-Trade unit, which is a fair price. The costs of the vehicles complete with batteries are taken at reasonable figures, starting with £200 for the small car, weighing 9 cwt. in all, and increasing at a uniform rate as the total weight increases.

Examination of the curves will show that, all things considered, the cars of group B, in which the battery, the car, and the load are equal, are the most economical and convenient. In this group, the useful load bears a constant ratio to the total load, and the cost of electric energy per ton-mile is also constant. In the example given, the cost is 0·55*d.* per ton-mile—a reasonable figure, which is based upon a price of 1½*d.* per Board-of-Trade unit, a draw-bar pull (tractive resistance) equal to 50 lbs. per ton, an output of 1 HP.-hour for 67·2 lbs. of battery, an all-round efficiency of 75 per cent., and a speed of 12 miles per hour. While the light load of group A is far more expensive to carry, and the heavy loads of group C a little less expensive, yet the curves showing the cost of running the vehicle empty place B between the two; and the curves of weights and costs, which would also be the curves of depreciation and interest, also place the cost of group B as the mean of groups A and C; so it would appear that the cost of running B either empty or fully loaded would be less even than the cost of running C under the same conditions. The Author submits that, all things considered, cars in which the weights of batteries, vehicle and load are equal, are the most suitable for electrically propelled vehicles. In group B, No. 1 would make a light pleasure carriage; No. 2 a victoria or coupé; No. 3 a brougham, cab, or light van; and so on.

Cost of Propulsion.

The last point for consideration is the cost of electric propulsion on common roads; and in order to put this question in a clear form, the Author has prepared Table V., giving the comparative costs of different systems of propulsion.

It is possible to drive electric vehicles on a good level road with an expenditure of only 50 watt-hours per ton-mile, at a cost of 0·1*d.* for electric energy, taking the actual cost of generating the electricity, with a fair profit, at 1½*d.* per Board-of-Trade unit. This cost will compare favourably with that for any other kind of self-propelled carriage (see Table V.); and renders electric pro-

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pulsion on roads, with its advantages already enumerated, more promising than any other system of motor-carriages.

In America, batteries are made which give a large output with a comparatively short life of the positive plates; and as the cost of such batteries is small, they can be entirely renewed, say, annually. This plan is stated to result in economy; and it may be the best way of applying the allowance for depreciation in Table V.

The difficulty of obtaining a fresh charge for the batteries is now being rapidly overcome, owing to the readiness of the electric-supply companies in towns and in country districts to provide motor-houses, and to recharge at all hours of the day and night, at a reasonable cost. Charging can be effected in every district in London and at Chelsea, Hampstead, Richmond, Windsor, Watford, Stratford, Leyton, Harrow, Chislehurst, Putney, all on main roads leading from London: farther out there are charging-stations at Guildford, Crawley, Woking, Tunbridge, Chelmsford, Luton, Cheltenham, Reading, Maidenhead, and other towns on the River Thames; and still farther afield the like facilities are afforded at Brighton, Southsea, Hastings, Oxford, Bath, Bedford, etc., and many other towns throughout the country.

The potentialities of electric propulsion of carriages on common roads are great; and the Author's aim is to call attention to the advances made, and to the possibilities of further improvement.

It is interesting to compare the results attained by electric automobiles, as described in the Paper, and those by electric railways, as given by Dr. Kennedy,[1] viz.:—

Electric Railways, etc.	Speed in miles per hour.	Watt-hours per ton-mile.
City and South London Railway	13·5	83·8
Liverpool Overhead Railway	15·0	70·0
Dublin Tramway	8·0	91·7
Waterloo and City Railway	14·0	41·8

The average tractive resistance on the electric railways is only 12 lbs. per ton, as against 50 lbs. per ton calculated for the electric automobiles.

[1] Minutes of Proceedings Inst. C.E., vol. cxxxix. p. 136.

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It appears to be desirable to fix upon a standard for the electromotive force to be used in electric automobiles; such a standard would be of great advantage to the designer and manufacturer of the automobiles, and of the motors, batteries, etc., used in them.

France, America, Germany and other countries are far ahead of England in regard to the manufacture of motor-cars; but the Author hopes that England will now take her place in the world with this new industry, as she did in the past with the steam-locomotive.

The Paper is accompanied by illustrations from which the Figures in the text have been prepared.

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APPENDIX.

TABLE I.—PARTICULARS OF EARLY AND OF RECENT ELECTRIC VEHICLES.

No.	Vehicle.	Weight of Vehicle Only.	Weight of Battery Only.	Ratio of Weight of Battery to Total Weight.	Remarks.
		Tons.	Ton.	Per Cent.	
1	Omnibus (London Electric Omnibus Co.)	2·5	0·75	23	Approximate limit of distance these earlier carriages will run on one charge stated to be 25 to 30 miles.
2	Omnibus (Electromotive Force Co.)	2·2	0·67	23	
3	Jeantaud Wagonette (France)	2·0	0·6	23	
4	Hansom cab (Electric Carriage and Wagon Co. of New York)	1·1	0·4	27	
5	Electric brougham (Morris & Salom, U.S.A.)	1·1	0·45	29	
6	Electric dog-cart and voiturette at Chislehurst trials, England, 1900	0·4	0·4	50	These later carriages will run 50 to 100 miles on one charge.
7	Columbia Carriage Co., U.S.A.	0·4	0·5	44	

TABLE II.—FIVE YEARS' PROGRESS IN ELECTRIC AUTOMOBILES.

	1901	1896
Weight of storage-batteries to give 2 B.HP. for 6 hours	7 cwt.	21 cwt.
Efficiency	80 per cent.	70 per cent.
Weight of electric motors to give 2 HP. at 600 revolutions per minute	1 cwt.	4 cwt.
Efficiency	90 per cent.	70 per cent.
Weight of carriage to carry four passengers	8 cwt.	20 cwt.
Ratio of weight of batteries to total weight	50 per cent.	23 per cent.
Watt-hours per ton-mile to propel carriages on good level roads	80	240
Cost of similar carriages	£300	£600
Maintenance per annum	20 per cent. = £60	33⅓ per cent. = £200
Cost of electric energy per ton-mile at 1½*d.* per unit	0·1*d.*	0·3*d.*
Distance carriages will run (on level roads) on one charge	50 to 100 miles	20 to 50 miles
Cost of electric energy per unit	1½*d.*	6*d.*

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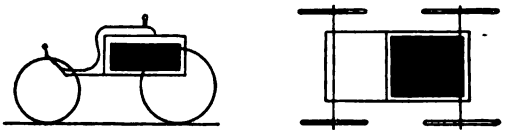
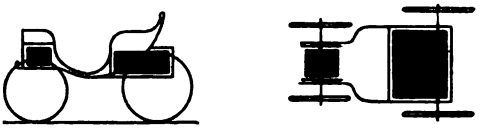
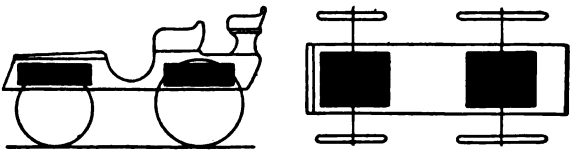
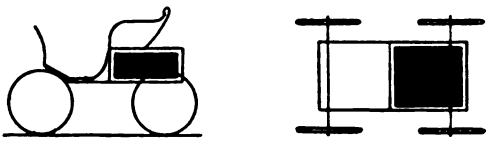
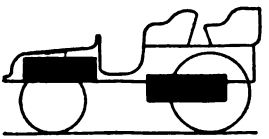
TABLE III.—ELECTRIC AUTOMOBILES.—

No.	Date.	Name and Description.	Outline Drawings of Cars—Scale $\frac{1}{8}$ inch = 1 foot. Battery in Black.
1	17 Nov. 1899	Electric Vehicle Co., Hartford, U. S. A. "Columbia," Runabout.	
2	14 May 1900	B. G. S. Co. (Bouquet, Garcin & Schivre Co.) France. "Criterium" Car.	
3	18 Oct. 1900	National Motor Carriage Synd., London. "Joel" Car Voiturette.	
4	June 1901	British and Foreign Vehicle Co., London. "Powerful." Touring Car.	
5	Sept. 1901	Baker Motor Co., Cleveland, U. S. A. "Runabout."	
6	Oct. 1901	Kriéger Co., France. Kriéger Car.	

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LONG RUNS ON ONE CHARGE.

Roads. Gradients. Weather.	Weights. (1 ton = 2,240 lbs.) Battery only.	Carriage only.	Load or Passengers.	Total Car Loaded.	Comparative Results. Ratio of Battery to Total Weight.	Ratio of useful Load to Total Weight.	Total Miles Run.	Speed in Miles per Hour	Watt-hours per Ton-Mile.	Remarks.
	B.	C.	L.	T.	$\frac{B \times 100}{T} = X$	$\frac{L \times 100}{T} = Y$	M.	S.	W.	
	Lbs.	Lbs.	Lbs.	Lbs.	Per Cent.	Per Cent.	Miles.	Miles	Watt-hours.	
Philadelphia to Atlantic City, New Jersey.	980	1200	420	2600 = 1·16 ton	37·7	16·15	100	13·3	130	Battery 48 cells, 95 to 78 volts, 154 ampere-hours capacity, efficiency 65 per cent. One 2 to 3-HP. series-wound motor, 85 per cent.
Not stated.	2781	2278	560	5619 = 2·5 ton	49·4	10·0	162·5	10	130	Battery 44 cells, 90 volts, 325 ampere-hours capacity.
London to Brighton, hilly road; sandy; fine for 40 miles, last 13 miles raining.	896	948	448	2292 = 1 ton	39	20·0	53	10	140	Battery 4 cells for fields, 32 cells = 32 to 28 volts, 2–16 sets parallel, 160 ampere-hours capacity, efficiency 80 per cent. Two 2-HP. shunt-wound motors.
	On good, hard, gravelled level roads . . .							12	86	
	"	"	"		"	"	. . .	14	119	
London to Reading and back. Good hard average road.	2464	1680	672	5040 = 2·2 ton	52·3	13·0	94·75	11·5	138	Battery 50 cells, 101 to 96 volts, 250 ampere-hours capacity. Two 4-HP. motors.
	On good, hard, level road							12	130	
Boulevards of Chicago, level city roads.	600	600	168	1368 = 0·61 ton	44	12·3	187·5	8	78	Battery 20 cells, Porter type. One ¾ to ½ HP. motor.
Paris-Bordeaux road; Paris to Châtellerault, Route nationale, good hard road.	2750	2145	605	5500 = 2·45 ton	50	10·0	190·3	12·4	115	Battery 60 cells = 120 to 102 volts, 400 ampere-hours capacity, Fulmen type.

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TABLE IV.—SOME OFFICIAL TESTS

No.	Date.	Name and Description of Car.	Roads, Gradients, Weather.	Weights. (1 ton 2,240 lbs.) Battery only. B	Carriage only. C	Load or Passengers L	Total Car loaded. T
	1899	French motor cab and van trials—	Good level roads, suburbs of Paris.	Lbs.	Lbs.	Lbs.	Lbs.
1	„	Jenatzy coupé . .	„	1,007	2,490	460	3,957
2	„	Jeantaud cab . .	„	890	1,881	460	3,231
3	„	Jeantaud drosky .	„	774	1,381	460	2,615
4	„	Kriéger victoria .	„	1,006	1,962	770	3,738
	1900	French automobile trials, Paris Exhibition, by Mr. Forestier . . .					
5	..	Riker delivery wagon	..	1,344	3,808	..	5,152
	Feb. 1900	Tests organized by *Electrical World and Engineer*, New York, and made by Mr. R. A. Fliess—					
6	„	Vehicle A — Light delivery wagon .	Level asphalte in good condition.	1,120	1,965	305	3,390
7	..	Vehicle B — Light delivery wagon .	„	1,250	2,130	334	3,714
8	..	Vehicle C — Light delivery wagon .	„	1,200	2,990	335	4,525
9	..	Vehicle A . . .	„	1,120	1,965	930	4,015
10	..	Vehicle A . . .	„	1,120	1,930	305	3,355
	1901	Further tests by Messrs. Sever and Fliess in New York— . . .					
11	„	Wagon	Level asphalte in good condition.	1,200	..	450	4,200
12	„	Wagon	„	1,200	..	450	4,200
13	„	Wagon	„	1,200	..	450	4,200

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OF ELECTRIC AUTOMOBILES.

Comparative Results.					Remarks.
Ratio of Battery to Total Weight,	Ratio of Useful Load to Total Weight,	Total Miles Run.	Speed in Miles per Hour.	Watt-Hours per Ton-Mile.	
$\frac{B \times 100}{T} = X$	$\frac{L \times 100}{T} = Y$	M.	S.	W.	
Per Cent.	Per Cent.	Miles.	Miles.	Watt-Hours.	
25·0	11·6	..	14·4	134	Battery, 44 Fulmen cells: efficiency given as 75 per cent. Average cost of electric energy taken at 0·4*d.* per ton-mile.
27·0	14·2	..	12·0	145	
29·0	17·6	..	16·0	131	
27·0	20·0	..	14·6	133	
26·0	..	..	7·0	125	Battery, 85 volts.
33·0	..	31·5	9·2	103	Solid rubber tires, wheels with ball-bearings; battery, 68 per cent. efficiency.
33·6	..	26·2	9·85	88	Solid rubber tires, wheels, armature-axle and with ball-bearings.
26·5	..	24·7	8·83	106	Solid rubber tires, no ball-bearings.
28·0	23·0	17·4	8·7	104	No. 6, with addition to load.
33·4	..	12·8	9·4	116	With pneumatic tires instead of solid rubber; wheels with ball-bearings, as in No. 6.
28·5	..	..	10·5	91	Draw-bar pull at 10·5 miles per hour = 39·26 lbs.
28·5	..	..	5·4	84	Draw-bar pull at 5·4 miles per hour = 36·3 lbs.
28·5	..	..	2·0	110	Draw-bar pull at 2 miles per hour = 36 lbs.

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TABLE V.—WORKING-COSTS OF VARIOUS

Items of Working Cost.	Horse.		Petrol.	
	London Cab to seat 4 Passengers and Driver, 30 Miles per Day, 275 working-days (2 Horses kept). Total Weight, with Passengers, 1 Ton.	Sever and Fliess. 1-Horse Wagon, making Three Deliveries a Day; 500 Lbs. Load, (2 Horses kept), 36 Miles per Day, New York City.	W. Worby Beaumont, M. Inst. C.E. One Motor Vehicle with Four Passengers and Driver. 30 Miles per Day for 200 Days in Year = 6,000 Miles. Total Weight = 1·2 Ton. Solid Rubber Tires.	The Automobile Club Trials of Reliability of Motor Vehicles. Motor Manufacturing Co., 6-HP. 1-Ton Van, carrying Load of 1 Ton and Driver on Five Days' successive Runs, average 90·6 miles per Day (8·8 Miles per Hour) = 187·9 Ton-Miles.
Cost of fuel, food, or electric energy per day	4*s.*	2*s.* 9*d.*	1*s.* 5*d.* at 1*s.* 3*d.* per gallon.	7*s.* 9½*d.* at 1*s.* per gallon.
Lubrication, repairs, and maintenance per day (275 working-days)	Cloths and shoeing, 6*d.*	Shoeing, etc., 6½*d.*	*s.* *d.* Repairs 0 5½ Tires 0 8 1 1½	Oil . 1*s.* Tools and Sundries 1*s.* 2*s.*
Rent, stables for horses and vehicles. Men in attendance per day; 365 days—per day	2*s.*	*s.* *d.* Horse stable 0 9½ Vehicle „ 0 4½ Labour . . 1 1½ 2 3½	11*d.* including insurance	2*s.*
Driver or attendant per day (6 days' work)	6*s.* 6*d.*	*s.* *d.* Driver . 7 1 Boy . . 4 9 11 10	6*s.* 6*d.*	6*s.* 6*d.*
Interest on outlay per annum, 365 days—per day	Vehicle £100 2 Horses 90 Harness 20 £210 At 5 per cent. = 7*d.* per day.	£ *s.* *d.* 2 Horses 52 1 8 1 Wagon 65 0 0 Harness 11 9 2 Total £128 10 10 At 6 per cent. = 5*d.*	4 per cent. on £410 = 10¾*d.*	5 per cent. on £400 = 1*s.* 1*d.*
Depreciation on outlay per annum, 365 days—per day.	20 per cent. on £110 and 10 per cent. on £100 = 1*s.* 9*d.*	At 10 per cent. = 8½*d.*	15 per cent. on £400 = 3*s.* 3*d.*	15 per cent. on £400 = 3*s.* 3*d.*
Total cost per day	15*s.* 4*d.*	18*s.* 6½*d.*	14*s.* 1¼*d.*	22*s.* 7½*d.*
Total cost per ton-mile	6·1*d.*	6·1*d.*	4·7*d.*	1·44*d.*
Cost per mile run	6·1*d.*	6·1*d.*	5·66*d.*	2·98*d.*
Cost of food, fuel, or electric energy per ton-mile	1·6*d.*	9*d.*	0·47*d.*	0·5*d.*
Cost of food, fuel, or electric energy per ton-mile of useful load	4·25*d.*	3*d.*	1·5*d.*[2]	1·03*d.*

[1] This depreciation of 20 per cent. on the whole cost is made up of 40 per cent. on the each 2 years; and there is still left 15 per cent. on the carriage and motors, in addition to

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METHODS OF PROPULSION FOR VEHICLES.

Steam.		Electricity.		Notes.
Light Steam (Petrol-Fuel). Pleasure Carriage to Seat Four, including Driver. 30 Miles per Day. 275 Days. Total Weight, including Driver, 0·8 ton.	Liverpool Self-Propelled Traffic Association, 1901. Steam Motor Wagon, 4 Tons. Good Macadam Roads. 45 Miles per Day = 180 Ton-Miles.	Author. Electric Cab or Brougham. 30 Miles per Day, 8 cwt. Load, Total 1·2 Ton. 120 Watt-Hours per Ton-Mile. Average London Roads. Solid Rubber Tires.	Sever and Fliess, U.S.A. Electric Wagon. 36 Miles per Working Day, 500 lbs. Load, Total Weight, 1·9 Ton. 120 Watt-Hours per Ton-Mile. Battery, 80 per cent. Efficiency. Current 1½d. per Unit.	*Liverpool Self-Propelled Traffic Association Trials, June, 1901.*
2s. 6d. at 1s. per gallon.	4s. 7d. Furnace coke at 15s.	8·4d. at 1½d. per unit.	1s. 3d.	Vehicle. Average Cost of Fuel per Useful Ton-Mile. Cost of Vehicle.
Oil, tools, repairs, etc., 1s.	5s. 5½d.	Oil and cloths. s. d. 2½ Rubber tires . 10 1 0½	..	d. £
				Milnes' oil lorry 0·99 550
				,, ,, ,, 0·80 550
				Lancashire Motor Co.'s steam lorry 0·23 582
				Thornycroft's steam wagon . 0·25 750
				,, ,, ,, 0·24 650
				Coulthard's steam wagon . 0·33 535
				Main's steam cart 0·31 465
				,, ,, lorry 0·29 500
				Petrol 1s. per gallon. Coke 15s. per ton.
1s.	Add 7½d. in place of insurance.	Rent of garage for 50 vehicles = £200 per an. Labour, £700 per annum = 1s. per day.	4½d.	*Calculated from Table III. Electric Automobiles.*
6s. 6d.	s. d. Driver 5 10 Boy . 2 11 8 9	6s. 6d. Mechanic.	s. d. Driver 7 1 Boy . 4 9 11 10	No. of Car. Cost of Electric Energy per Ton-Mile at 1½d. per unit. d.
				1 . . . 0·24
				2 . . . 0·24
				3 . . . 0·28 / 0·16 at 12 miles per hour.
				4 . . . 0·26
				5 . . . 0·15
				6 . . . 0·21
				After adding 25 per cent. for loss in charging.
5 per cent. on £300 = 10d.	5 per cent. on £600 = 1s. 7½d.	1 cab, £350, at 5 per cent. = 11½d.	1 wagon, £478, at 6 per cent. = 1s. 7d.	
15 per cent. on £300 = 2s. 5½d.	15 per cent. = 4s. 11½d.	At 20 per cent. on £350 = 3s. 10d.[1]	At 10 per cent. = 2s. 7½d.	*Motor Cab Trials made by the Automobile Club of France, 1898.*
				Cost of Electric Current per Ton-Mile. d.
14s. 3½d.	26s.	14s.	17s. 7¾d.	Jenatzy coupé . . 0·24
7d.	1·7d.	4·6d.	2·75d.	Jeantaud cab. . . 0·23
5·7d.	6·9d.	5·6d.	5·5d.	Jeantaud landau. . 0·24
				Kriéger coupé . . 0·21
				Kriéger victoria . . 0·23
1·25d.	0·22d.	0·18d.	0·225d.	Kriéger coupé à galerie . . . . 0·2
3·3d.	0·3d.	0·53d.	1·4d.	Mr. Worby Beaumont gives the average cost of petrol in present motor-cars as 0·5d. per ton-mile.

batteries, which, with a rebate for old materials, is equivalent to an entirely new battery allowance for tires. [1] This would be increased to 2d. if taken on 275 working-days.

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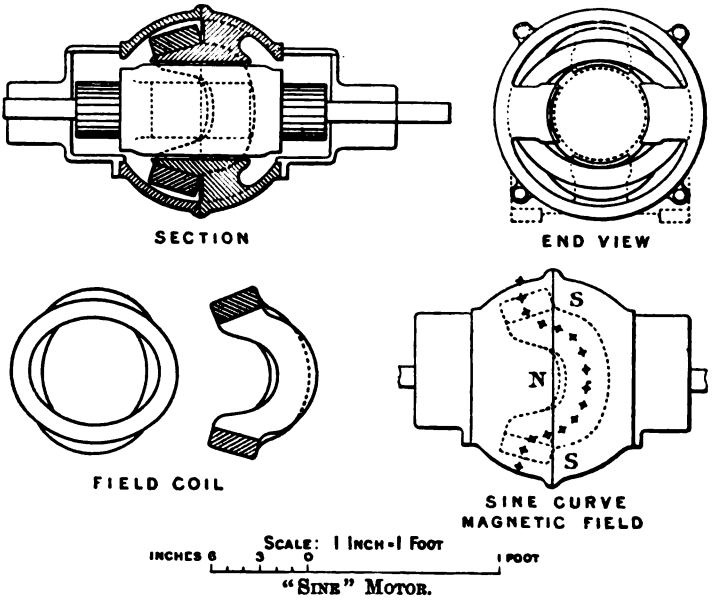
Discussion.

The President. The PRESIDENT, in proposing a vote of thanks to the Author, remarked that the Paper was interesting to the members not only as engineers but as citizens, because the development of the automobile was likely to be far-reaching in its effects.

The Author. The AUTHOR described a new motor which he had devised for electric automobiles. It was a four-pole motor, spherical in shape, with the iron casing carrying the poles divided in the centre into two halves, each half having two poles, and the two halves with their poles interspacing when placed together.

Figs. 42.



"SINE" MOTOR.

A single field-coil of special form was used for magnetizing the four poles. A front and side view of this coil were shown in *Figs. 42*, and the coil in position, relatively to the poles, was shown in the section. The coil was wound directly on a ball mould, or spherical former, or alternatively was first wound as a simple ring, and afterwards pressed or moulded into the required form, having two curved indentations alternating with curved raised parts, sinuous in shape, hence the name "sine motor." This coil was placed in position on one half of the iron casing, partly embracing and including the two poles on the

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magnetizing sphere of the coil, the other half of the iron casing with its two poles fitting into the depressions of the coil, and in turn being also included in the magnetizing sphere of the coil. The one coil magnetized the four poles alternately in two pairs, N.N. and S.S. It was found that this one magnetizing field-coil was only about one-half the weight of the four separate coils ordinarily used in a four-pole motor, and the C^2R loss was approximately only one-half. The sine-curve magnetic field (*Figs. 42*) allowed a reduction of the iron casing of 1 to 0·6, with a proportionately reduced weight, and a feature which he submitted was of the greatest importance was that the resultant direction of the field-coil and current being parallel and opposite to the current in the armature-coil windings, the point of commutation was thereby more defined, and a sparking limit, or permissible ampere stream, double that usually calculated for salient pole motors with separate coil windings, was obtained with the "sine motor," with fixed brushes, for rotation in either direction. Consequently a very light electric motor having a great output and high efficiency was the result. A "sine motor" with a double-wound armature and two commutators (*Figs. 42*) gave 6 B.HP., and weighed only 190 lbs.; the exciting energy was 70 watts, the efficiency 87·5 per cent. These results and the sparkless commutation were of considerable advantage in a motor intended for use in an electric automobile. He had been testing this motor for 2 or 3 years past, and as it had not been described before, he had thought it would be interesting to show it in connection with the Paper. He would like to add a few words on the usefulness of the electric automobile. As an auxiliary to electric supply-stations, and to electric railways and tramways, it seemed to him to have a great future. He had felt somewhat diffident in bringing the subject before the Institution, on account of its novel character, and he had had a little doubt as to whether it would be acceptable; but he thought the subject would become of great importance, although it was still in its infancy. From a sanitary point of view, and from the point of view of the transport engineer, the use of electric automobiles would be one of the most serious questions of the near future. Having recently had occasion to inquire into the cost of horse-drawn mails from London, he had ascertained that ten mail-coaches were driven out of London every night, to various towns, and travelled a total distance of 380 miles; and the cost of conveyance worked out at 6*d.* per ton-mile, the weight of the vehicle and the driver being included in the calculation. In the examples of Table V. the total

The Author.

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The Author. cost per ton-mile for the horse-drawn vehicles worked out at 6·1*d.* in both instances; and it was a curious coincidence that the actual cost of carrying the mails by horse-drawn vehicles worked out at practically the same figure. As would also be seen from Table V., the cost per ton-mile for electric vehicles was about one-half of that. The Post Office had recently made trials of electric vehicles. The Pioneer Electric Power Company were running an electric mail between London and Redhill, a distance of about 21 miles, which had been fairly successful. The Post Office had also tried an Opperman electric vehicle in London from the south-western district office to Battersea. The vehicle had been running experimentally for 12 weeks, and was reported to have been highly successful. Hence it seemed that, if more energy and attention were given to the subject, electric vehicles could and would be successful for such purposes. He had given in the Paper some particulars as to the watt-hours per ton-mile on electric railways. Taking 83·8 watt-hours per ton-mile, as given by Dr. Kennedy, for the City and South London Railway, and a tractive resistance of 12 lbs. per ton, the energy-consumption of road-vehicles, reduced to the same tractive resistance, was found to be less than one-half, namely, 32 watt-hours per ton-mile: which showed the economy of self-contained electric vehicles. The reasons for the economy were, that there were not the heavy capital charges, the cables, and the sub-stations of electric tramways and railways, and the vehicles had not to be made strong enough to bear the strains of pushing and pulling incurred by coupled vehicles. The recent interesting and able Paper on electrical traction on railways,[1] presented to the Institution by Messrs. Mordey and Jenkin, had been followed by a Paper on electric tramways[2]; and he had now completed the series by dealing with electric automobiles, which would serve where the other systems stopped, and would carry goods and passengers from the ends of electric tramways into districts where it would not pay to put down lines. He thought he had shown that such vehicles could be made economical and practical. As mentioned in the Paper, the weight of the batteries had been reduced considerably within the past 5 or 6 years, and in that respect electric cars now compared favourably with petrol and steam cars. The average weight of a petrol car varied between about 10 cwt. and 25 cwt.; a good petrol car would weigh about 17½ cwt. to

[1] Minutes of Proceedings Inst. C.E., vol. cxlix. p. 40.
[2] *Ibid*, vol. cli. p. 39.

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20 cwt.; electric cars could be obtained weighing 19½ cwt. to 20 cwt. He had not touched in the Paper upon the many other kinds of batteries, motors and carriages, which were probably known to the members. There was a combined petrol and electric motor and many others, which he hoped would be described by engineers who were more familiar with them than he was. The Author.

Mr. A. B. CHATWOOD remarked that he had lately had to design some electric automobiles for a firm of steel-merchants, and it might perhaps be interesting if he described why electric vehicles had been insisted on instead of steam-lorries. In this case, a steam-lorry could not be obtained which had the flat top necessary for carrying long girders, the duty for which these lorries were intended. The insurance companies, too, had something to say in the matter. He had advised one firm, in the first instance, to order steam-lorries; but on making inquiries they had found that, as a rule, the insurance companies would not allow them to be used for cotton carrying. The district in which he lived was full of cotton-mills, and he believed the companies would not allow either petrol-lorries or steam-lorries to enter such mills to load. He did not know yet whether they would allow electric lorries to do so; but if they would, there was a large field, at all events in the south of Lancashire, for heavy lorries. He questioned the necessity, at the present day, of using a spring connection between the motor and the underframe. He did not see why motors with slotted armatures could not be built capable of standing any shock to which they would be exposed; in fact, he thought the motors that were being built would stand such shocks. The shock sustained by the motors of an electric automobile would not be as severe as that of an electric tramcar taking points. Another feature of design, which was of great importance and was mentioned in the Paper, was the rigid connection between the front and back wheels, instead of trusting to springs. One curious fact had transpired in connection with the lorries he had referred to, which was not brought out by any of the diagrams in the Paper, namely, that it was essential that the front axle should be able to turn through a right angle, so as to become parallel with the axis of the lorry; because, in delivering goods, these lorries had to go into narrow alleys, and turn sharp corners. The horses of horse-lorries sometimes had to be taken out, and the lorries manœuvred round. In South Lancashire, therefore, there seemed to be a greater opening for heavy lorries, carrying loads of 4 to 6 tons, than for the pleasure automobile. The lorries he had referred to were intended to carry a 5-ton load; Mr. Chatwood.

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Mr. Chatwood. their weight was approximately 5 tons, including the batteries, which weighed about 30 cwt.; they were intended to run a maximum of 30 miles, and to be capable of running at 8 miles per hour, which was just twice the speed allowed by law.

Prof. Ayrton. Professor W. E. AYRTON considered that the Paper was an interesting one, on an interesting subject; and in view of the previous failures of accumulator-traction on common roads, he thought it had required a great deal of courage on the part of the Author to attack the problem practically as he had done, and to give the results obtained by himself and by others. In view of the fact that practically all the uses of electric accumulators for public, as distinct from private, electric traction had been failures, it was necessary to be an enthusiast in order to tackle the question. The Author was an enthusiast: and were not enthusiasts apt to be a little rosy in their views of what could be done? For example, the Author said that the watt-hour storage-capacities per pound of a complete cell, given on p. 10, were the values stated by the manufacturers. Manufacturers also were enthusiasts, and looked at the matter from an optimistic point of view. In the case of the Fulmen accumulator, which had been so much used in France, it was stated that 11 watt-hours storage-capacity per pound of complete cell could be obtained. The results of the prolonged series of trials of various accumulators made by the Automobile Club of France in 1899, however, showed (p. 11) that with this cell 101·9 total kilowatt-hours were obtained in ninety-eight successive discharges of a battery weighing 148·5 lbs. If those figures were worked out they would not come to 11 watt-hours, but to less than 7 watt-hours per pound. He was inclined to think that the storage-capacity of accumulators was much over-rated. From time to time many kinds of cells had been sent to him to be tested, but he had never obtained such figures as were frequently claimed for their storage-capacities. For instance, the manufacturers of the Rosenthal cell gave 15 watt-hours per pound; he had not tested that particular cell, but he had never obtained such a figure with any cell; about 8 watt-hours was the highest he had ever obtained over a long series of charges and discharges. That made a great difference in an estimate of the distance it was possible to run with an accumulator in a motor-car; because if there was less storage-capacity for a given weight, and it was necessary to go a certain distance, the weight would have to be increased, which meant increasing the output of the battery per mile in order to propel that weight, and therefore led to a still further weight of cells having to be carried. At the beginning of the Paper an

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interesting account of the different kinds of batteries was given. On p. 6 a battery was mentioned wherein zinc with peroxide of lead was used, and the Author stated that this battery had the advantage that it could be charged quickly, and the whole energy could be stored in an hour or two. No doubt that was true; but it might be imagined from the statement that only that kind of battery, having zinc, could be quickly charged. In order to test that particular point, a series of experiments had been carried out in his laboratory, in 1898, the results of which had been communicated to the British Association in the same year. Accumulators were usually charged with a comparatively small current, a current much less than might be put through them—the current, for example, that they were discharged with. The particular accumulator tested in the investigation had been a Tudor cell—rather a small cell with only five plates—the rated current for charging being 20 amperes. It had occurred to him to try the effect of applying a constant potential difference instead of charging the cell for some hours with a constant current of 20 amperes. When charged with this constant current, the potential difference between the terminals per cell had risen from 2 volts to 2·55 volts. It had taken 206 minutes to put in 152 watt-hours. The question was, what would happen if practically the final potential difference were started with—if instead of allowing the potential difference to rise slowly from 2 volts to 2·55 volts, the current being kept constant, 2·55 volts were applied to start with, and the potential difference were kept constant at this value? Of course, relatively the current became enormous—over 160 amperes at the start. A large number of tests had been made in two distinct ways. He believed in testing cells only when a certain cycle of charging and discharging was carried out over and over again for weeks, until the cell had got into an absolutely steady condition. Single charges and discharges of cells told nothing: they might show that the cell was bad, but nothing else. The cell had first been charged and discharged, in the ordinary way, about forty-five times, until the charging-curves had become perfectly regular, and identical for successive charges and discharges. Having thus been got into a normal state for constant current, the cell had then been charged and discharged about forty-five times with a constant potential difference. It had been found that a larger number of watt-hours—that was, more energy—could be put into the cell in 1 hour when it was charged in that way than in 206 minutes when charged in the other way: with the advantage also that during the 1 hour's charge at 2·55 volts

Prof. Ayrton.

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Prof. Ayrton. there was no gassing. The other questions to be decided had been, of course, whether the efficiency of the arrangement was lowered, and whether the cell was damaged. With constant current (for 3 hours), the energy efficiency of the cell had been 81 per cent.: whereas with charging at constant potential difference for 1 hour the efficiency had been 71 per cent. The efficiency had thus been about 10 per cent. lower; but both the amount of energy put in and the amount of energy got out in the discharge had been a good deal higher. Whether the cell had been charged at constant current, as in the first series of tests, or with constant potential difference, as in the second series, it had been discharged in exactly the same way; so that the results were quite comparable. It had been found that with constant potential difference 226 watt-hours were put in, as compared with 152 watt-hours when charging with constant current, 163 watt-hours being got out as compared with 123 watt-hours; so that under the latter conditions not only had more energy been put in but more energy had been got out, and the cell had had a greater storage-capacity, although its efficiency had been less. The question had then arisen whether the cell had been damaged by the forty-five charges and discharges with the constant potential difference, starting with 160 amperes instead of 20 amperes. The experimenter had therefore at the end gone back to the first set of tests, namely, charging with constant current, in order to ascertain the possibility of repeating the original observations. It had been found that this could be done; and there had been no sign whatever of the cell having been damaged. Although tested in 1898, the identical Tudor cell was still in use; which was the best proof that the treatment described had not damaged it. He did not know whether it was generally realized that a cell could be charged in that way, diminishing the time to less than one-third, and increasing not only the energy put in, but also the energy got out in the subsequent discharge. In addition to the many cells described by the Author for traction purposes he would like to mention one which Mr. Fithian, who was now with the Tudor Company, had worked out when studying under him. He had obtained a number of figures in relation to the working of this cell, but as he had had only about 1½ year's experience of it, he would not place them before the members yet. The cell was made in the following manner. First there was a thin sheet of ebonite, with perforations in it. It was quite possible, when that was put into a proper mould, to cast lead round it, and to have lead pieces across, so that the thin sheet of ebonite was interlaced with lead. That could be done without burning the

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ebonite, although at first sight it might be thought that the ebonite would be damaged. The plate was then pasted in the ordinary way; and as the foundation of the plate consisted of a substance which was not acted on by acid, the plate never fell to pieces. The great trouble in accumulators, especially with heavy discharges, was that after a short time the plates crumbled to pieces. That had never happened in this particular cell, within the 1½ year's experience already obtained. So far as that experience went, the result arrived at was that a plate made in the way he had described seemed to be extremely durable. He would like to see this kind of plate tested by a prolonged period of hard work in an accumulator motor-car. Hitherto that had not been done; the tests had all been made in the laboratory. The important point of the question of the fall in efficiency was dealt with on p. 11, where the Author spoke of a cell weighing 67·2 lbs. having a durability of 3,000 ton-miles, and losing only 10 per cent. of its efficiency. These figures were very good, and were far better than those obtained in the trials made by the French Automobile Club. As the Author said, cells had improved greatly since the tests made in 1899; but at the same time it was worth while examining the results quoted. The cell referred to as giving 1 HP.-hour for 67·2 lbs. weight needed about 11·1 watt-hours per pound. That meant a large storage-capacity to start with. Consequently, if 100 watt-hours per ton-mile were taken, as was done by the Author on p. 11, 3,000 ton-miles meant about four hundred full discharges, so that in four hundred full discharges the efficiency of the cell fell only 10 per cent. But the Fulmen cell in the Table on the same page, which had been one of the most successful cells in the trials made in Paris in 1899, had had only ninety-eight discharges instead of four hundred, and had lost 14 per cent. in efficiency. While therefore a cell was required which with four hundred full discharges would lose only 10 per cent. of its efficiency, one of the best of the cells in the Paris tests had had only ninety-eight full discharges, and had lost 14 per cent. in efficiency. He was afraid he would be considered rather a "wet blanket"; but it had unfortunately been his lot during the past few years to be a wet blanket to many proposals to start accumulator traction. At a discussion[1] in 1897, at the starting of the London Electric Cab Company, he had given reasons for his belief that the Company would be a failure, but he had ended by saying that nobody was more anxious and no one would be happier

Prof. Ayrton.

[1] Journal Institution Electrical Engineers, vol. xxvi. p. 689.

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Prof. Ayrton. to be proved wrong than he himself. On p. 5 the Author spoke of 86 watt-hours per ton-mile as required by an electric vehicle on a level road, and on p. 30 he said it was possible to run electric vehicles on a good level road with an expenditure of only 50 watt-hours per ton-mile. The actual results with the cabs of the London Electric Cab Company, which had made a long trial with many cabs, were the following. The weight of the cab, as mentioned in the Paper, had been a little over 2 tons, including everything except the two passengers and the driver, making the total weight about 2¼ tons. The accumulators had given 80 volts pressure; the current on good level paving had been 30 amperes, which had risen to 50 amperes on a rough road. That meant that between 2,400 watts and 3,600 watts had been developed, whereas going up-hill the power had been 8,000 watts. Assuming a speed of 6 miles per hour, and weight of cab 2¼ tons, the figures came to about 230 watt-hours per ton-mile. That was the figure which had been found absolutely necessary in the vehicles of the London Electric Cab Company, instead of the small figures of 50 watt-hours and 86 watt-hours per ton-mile, given in the Paper. With regard to the resistance of a vehicle with pneumatic tires, a number of careful experiments had been made by some of his students in order to find the pull necessary to drag a Beeston Humber bicycle in good order, with Dunlop-Welch tires, and a Humber block chain. The bicycle had had one person on it, and had been pulled by another person on a second bicycle. The draw-bar pull and the speed had been carefully measured. The speed had varied between about 3 miles and 18 miles per hour; and the tractive effort required had been found to be about 32 lbs. per ton on concrete, 49 lbs. per ton on macadam, and 43 lbs. per ton on wood blocks. Taking 41 lbs. per ton weight on a fairly level road as the mean, that gave almost exactly the same as the Author's higher figure of 86 watt-hours per ton; but in so doing no allowance was made in the bicycle trials for loss of power in the motor and in the gearing. The second bicycle had been pulled by the first; it had not been propelled by a motor, with its gearing and consequent loss of power. If power required to cover these losses were added, considerably more than 50 watt-hours or 86 watt-hours per ton-mile would be found to be necessary. In Table IV. one case showed 145 watt-hours per ton-mile, while at the bottom of the same column another case went down to 84 watt-hours per ton-mile: he would much like to have been present when the last figure was measured. Lastly, he wished to deal with one other point, namely, the reason for the failure of the

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London Electric Cab Company. Obviously every one who had dealings with accumulators and road traction would like to know that. Various explanations had been given at the public board meeting, one attributing it to the sensitiveness of the drivers, who had been too much ridiculed by their friends, because there were no horses in the cabs. On a previous occasion he had mentioned publicly the cause of the company's failure, and he presumed there would be no objection to his repeating it. The cells, of the Faure-King type, had been maintained by the Electrical Power Storage Company. Before the signing of the contract, that company had offered the London Electric Cab Company two alternatives. If the Cab Company was willing to discharge its cells every other day, and to have them charged on alternate days, the Electrical Power Storage Company was willing to maintain them up to a certain fraction of their original capacity, for a payment of 10 per cent. per annum on the original cost. But if the Cab Company wished to discharge them every day—which was what they had elected to do—and to have them charged each night, then the payment under the contract was to be 20 per cent. per annum on the original cost. One proviso had been put in, to which the Cab Company had paid absolutely no attention; no doubt they had thought it was a sort of laboratory matter, an insignificant thing, which to an important undertaking like the London Electric Cab Company did not matter at all. This little detail had been the stipulation that any cell allowed to discharge so that the E.M.F. between the terminals fell below 1·8 volt, should not come within the contract. The first cases had been all right; as the cells had lost their storage-capacity, the Electrical Power Storage Company had renewed the plates. But after a time cabs had come in in which the cells had obviously been discharged until the E.M.F. between the terminals was less than 1·8 volt. The company had said at once that such cabs were outside the contract, and quite rightly so; and gradually cab after cab had gone outside the contract, until at last all of them had been in that position. He referred to that matter because he was not aware—although he would be glad to be told that he was mistaken—that in any electric vehicle propelled by accumulators the driver had a means of knowing when the E.M.F. per cell had fallen to 1·8 volt; he had no alarm bell, or anything of that kind. It might be asked what harm there was in allowing the voltage to fall below 1·8 volt? That subject had also been investigated in his laboratory in 1889; the problem being to ascertain to what voltage it was possible to allow the cell to fall without causing

Prof. Ayrton.

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Prof. Ayrton. damage, charging and discharging it between definite voltage limits. There had been absolutely nothing to guide the experimenters. First of all 1·55 volt had been used, and then 1·6 volt; but after a time the cells had been found to be rapidly losing their capacity. Finally the fact had been arrived at that if the voltage was allowed to fall below 1·8 volt, the capacity of the cell diminished rapidly.[1] Although he had not been aware of it, the problem had been attacked at the same time by Professor L. Duncan and Mr. H. Wiegand in Baltimore; and they had published,[2] almost simultaneously, the same answer. Every accumulator company now put in its contracts the stipulation that they would not maintain the cells at a given rate, unless that limit of voltage was never reached. The reason why the effect was so disastrous if the voltage fell below 1·8 volt was simple. Such a fall in the voltage meant that there was not enough sulphuric acid: instead of sulphate being formed on the plate, and instead of the double sulphation theory of the working of the cell holding, there was soluble hydrated lead oxide, which wandered about in the cell and was turned into *detached* sulphate. Not being on the plates, the detached sulphate could not be reduced in the next charge, and the consequence was that the capacity fell rapidly; and, as had been found in the experiments referred to, a deposit of $PbO_2 + PbSO_4$ fell to the bottom of the cell, and the plates became disintegrated. He urged that, in order to obtain success with accumulator-traction, the same precautions must be used as were taken in the laboratory and in the central station. The cells must not be allowed to discharge below 1·8 volt. An indicator must therefore be put in front of the driver, which rang a bell or other signal, some time before the danger-limit was reached; and the driver should be given to understand that, if he did not come back to the charging-station when the bell rang, his dismissal awaited him on his return.

Mr. Clarkson. Mr. T. CLARKSON entirely agreed with Professor Ayrton's comment on the Author's rosy views. Perhaps it was not surprising that such opinions should be held by electricians or electric automobilists; but surely the same opinions might be held by a steam or a petrol automobilist. At the present time it was not unreasonable to say that the electric automobile might be regarded as the petted child of automobilism; it was unable to compete on level terms with either steam or petrol cars. Special conditions, shorter

[1] Journal Institution Electrical Engineers, vol. xix. p. 561.
[2] Transactions American Institute Electrical Engineers, vol. vi. p. 217.

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distances, had to be provided in all competitions: and there could scarcely be anything more absurd than that, in weighing electric automobiles, the competitor was allowed to leave out the weight of the accumulator, whereas in weighing a steam or petrol car the competitor had to weigh everything. The Author stated early in the Paper that tours of over 1,000 miles had been made satisfactorily, but nothing was said about the degree of satisfaction; the assertion was evidently meant to be taken as a proof that electric automobiles were suitable for general touring purposes. He did not think a single such example was very conclusive. He had been present at the time of the tour to which the Author referred, and had seen something of the car's journeyings. It could fairly be said that it had run very satisfactorily, if it was regarded from the point of view of keeping within the speed-limit of 12 miles per hour: it had certainly been a law-abiding car, for he had never seen it run at more than 12 miles per hour, unless perhaps when going downhill. But the general opinion of other automobilists who had witnessed its performance seemed to be that it might be described as a kind of overgrown insect crawling over the face of the earth and sucking the blood of every colliery it came across. That beautiful white-painted carriage, having to go to collieries to re-charge, was given as an example of pleasant touring; although it was subsequently said in the Paper that charging-stations were now becoming very numerous, and no difficulty was experienced on that score. But how would an electric carriage compare with a steam or petrol car under such conditions as had been formulated for the forthcoming September trials of the Automobile Club? A committee of representative manufacturers had drawn up conditions, and it had been suggested that a fair trial of the cars could be made only by confining them strictly, at the end of each day, to a reserved enclosure. Immediately they came back from the trial, the cars must not be touched: no cleaning or replenishing or repairs ought to be done. Next morning, before anything could be done in the way of replenishment, adjustment, or repairs, an observer should take his seat on the car, and after a signal was given the car could be repaired; but every minute occupied in the replenishing, adjustment, or cleaning, counted one mark against the car until it was ready to move under its own power. Could an electric car compete with either of the other kinds under such conditions? He thought it would be agreed that at the present time the electric carriage could not be considered to compare with petrol or steam carriages for general purposes. He

Mr. Clarkson.

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Mr. Clarkson. admitted at once that there was a field of usefulness for the electric carriage. For town service, within definite limits from its base of operations, it was eminently suitable, because there the conditions of working were not governed by questions of cost: people liked the electric automobile, and they would have it. The Author stated that an electric automobile was the only one in which the motor could be used as an effective brake. That was entirely wrong. Any one who had ridden upon a properly-constructed steam-carriage appreciated the immense braking-power of the compression of the engine. With an engine which was—as it ought to be for a steam-car—unbreakable, the easiest way of stopping was merely to pull over the reversing-lever, steam being shut off. That was the pleasantest way of pulling up the car, and it was done very quickly. The brake was not suddenly applied, although it appeared to be, the compressive effect being cumulative. The real question at the root of electric automobiles was the accumulator. Some years ago, Lord Salisbury, who had been experimenting on the subject, had remarked that Nature appeared to have conspired against the electric automobile, in having given practically only one element which could be used successfully in the construction of storage-batteries, a metal which possessed the great disadvantages of weight and weakness, whereas what was required was lightness and strength. All the ingenious arrangements shown in *Figs. 1–17* for utilizing lead and paste were so many ways of trying to make the best of a bad job. The materials available were poor. What hope there was of getting better materials he did not know; but until such were available he had little hope of the electric car superseding other kinds. On p. 10 the Author mentioned that particulars of the Edison cell could not be given. That cell had been referred to a few years ago as having solved once for all the question of road traffic. When the first announcement had been made, it had doubtless come as a tremendous shock to many who had been spending years and a good deal of money in investigating in other directions, to see their schemes vanish, and to picture the electric carriage superseding all others. But the shock had gradually subsided; the cell had not "materialized." Subsequent announcements had been made at various times; but with each announcement the cell had appeared to be weaker, until, at the last announcement, the cell had been so weak that it had failed to excite any apprehension. In common fairness it should be said that Mr. Edison gave to journalists the full credit of producing his last cell. He would like to give some comparative

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figures with regard to the cost of running an electric and a steam car. The depreciation in efficiency of the cell was given in the Paper as 10 per cent. after doing 3,000 ton-miles. The depreciation in value was not given; but it appeared that the figures mentioned represented the effective life of the cell. The depreciation in value would therefore probably be 90 or 95 per cent.; but the Author did not say what the scrap value of the cell was. He had recently made some careful experiments in regard to depreciation on steam cars. After running 4,000 ton-miles, he had had an engine taken to pieces and carefully examined. The engine was made with large surfaces (most of them hardened), was thoroughly well lubricated, and was protected from grit and dust; and he had been delighted to find the surfaces in splendid condition. There had been practically no evidence of wear, and to all intents and purposes the engine had been as good as new, after running 4,000 ton-miles. He was satisfied that the steam-engine properly made would run 30,000 miles before needing repair, and then it could be put into good condition—made virtually as good as new—for about one-fifth of its first cost. That meant that the depreciation of the steam-engine, after running 3,000 ton-miles, would not be more than 2 per cent., as compared with 90 per cent. in the case of electric automobiles. Mr. Clarkson.

Colonel R. E. B. Crompton, C.B., remarked that, although the Paper was interesting and instructive and contained a mass of information of great use to every one connected with the electric automobile industry, it had been severely criticized. He admitted that, in some respects, the Author was over-sanguine; but he thought a middle course between the two sets of opinions was the safe one. Those who looked carefully into the matter would see that, for town use, at all events, the use of electric automobiles ought to be encouraged in every way, if it were only for the fact that they were motor-cars which could be driven by unskilled persons. Ladies could drive themselves, without the need of having any attendant; and moreover, sudden breakdowns were not liable to occur on electric cars. Sufficient warning was generally given that a car required attention, so that it was unlikely that people driving one would be stranded in the street. At present an increasing number of electric cars were to be seen in the streets of London. It would perhaps surprise Professor Ayrton to hear that the number now running was nearly thirty-fold the number owned by the London Electric Cab Company, about which he had spoken. That company had made an early and valuable experiment; and, although it had Col. Crompton.

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Col. Crompton. failed, it had furnished an interesting object-lesson to all electrical engineers. He, like others, had studied the working of the company, and had found that, as was usual in such cases, its failure could not be ascribed to the accumulators, or to any one cause in particular. Defects in design, unsatisfactory charging-arrangements, and similar causes, had each contributed to the failure; nevertheless a gallant attempt had been made, and success had nearly been reached; and it must not be argued that similar attempts made at the present time would also be failures. It was believed that at present the cars now running in the streets of London were a commercial success; but the number in London was small compared with those to be seen in the streets of Paris. In that city recently he had been struck by the fact that quite a large proportion of theatre-goers who used carriages used electric automobiles. In his opinion there was every reason to encourage the use of electric vehicles. The supply of electricity for charging them was a very important matter to the electric-supply companies, as it enabled them to utilize their entire plant during the hours of light load. It thus enabled them to spread their working-expenses over a larger output, and to reduce the average cost of the energy produced. In the end, it must also benefit the public, because it must lead to eventual reduction in prices, even for lighting. He believed that the use of electricity for driving electric automobiles might expand so greatly that it would double, or even quadruple, the load of lighting-stations, and would have a most important effect on their future. For that reason he thought shareholders and all interested in electric supply ought to encourage the electric automobile. He did not attach much weight to the arguments of Mr. Clarkson, who had made a strong case against the use of the electric automobile for long-distance running, because the subject under discussion was, he considered, directed principally to the use of electric automobiles within towns, as a means of reducing the number of horses, and the consequent manure, slush and mud in the streets, which attend the use of horse-haulage. The engineering question, which would govern the commercial one apparently, was whether it was necessary to wait for a new form of accumulator from Edison or any one else. Were not the well-known accumulators at present fitted in the electric cars, such as had been made for years past with ordinary pasted plates, good enough for the purpose, provided that proper organization were adopted so as to secure their cheap and easy maintenance? He believed this could be done. He agreed with the Author that the time had

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Col. Crompton.

come when, if the matter were put into capable hands, and carried out on a sufficiently large and well-organized scale, the use of electric automobiles would be a great commercial success. Public services of vehicles, private carriages, tradesmen's carts and wagons could all be driven by electricity at a price considerably below what they cost for horseflesh, and in addition would offer very considerable sanitary advantages, cleanliness, and extra speed. He repeated that it was now a question of organization; all that was required was a system of interchangeable accumulators, with battery-charging stations at which an empty set could be exchanged for a fully charged set. Whether the carriages were privately owned, or were hired from a company, it would be necessary that they should all be made to take accumulator-boxes of a standard size. If there were twenty or thirty charging-stations spread over London, the user of an electric automobile would never be far away from one of them, so that if he noticed that his battery was running down he could exchange it, and then continue his journey. Up to the present, attempts had been made to increase the life of accumulators and to make them more durable: what was now wanted was a thoroughly organized system of repairing and maintaining them, so that they might be kept as good as new at a small cost. Material and labour for accumulator-repairs were not expensive, and by improved organization alone the cost of these repairs could be reduced to a low figure; so that he thought the future was hopeful. With regard to the Paper itself, there were some statements in it which required explanation by the Author. He had taken the trouble to check some of the figures given, and he agreed with Professor Ayrton that the watt-hours per ton-mile given in Table III. were somewhat astonishing. It was a pity that any of the figures should be overstated. He thought there must be some error in them. He had spent a good deal of thought lately on traction problems, and had always considered the electric automobile to afford one of the best methods of measuring tractive power absorbed by automobiles on highways, as the varying resistance was always accompanied by a movement of the needle of the ammeter: moreover, by putting a meter on the car it was possible to integrate the power required over any length of time. He had hoped that the figures given by the Author would throw some light on a matter in which he, personally, was much interested, namely, the power absorbed by air-resistance at speeds exceeding 10 miles per hour; and also that it would give some indication of the extra power required on an undulating as compared

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Col. Crompton. with a practically level road. As the Author stated, when descending a hill the car did not give back the whole of the power that had been used in ascending; consequently he had expected that the integrated power ought to show that a car running on an undulating road required a larger average draw-bar pull than one travelling on the level, just as if it had a continuous gradient against it. He found, however, in working out the figures in Table III. of the Appendix, that they varied among themselves to such an extent as to render it impossible to get concordant results from them. In the body of the Paper were shown some interesting methods of transmitting the power to the two wheels, and he thought users of cars would be much interested in the simple method of avoiding the use of differential gear shown in *Fig. 23*, where the armature drove one wheel and the field-magnet drove the other; but in this figure there was something wanting, for as far as the illustration went it would show that one wheel would be driven forward and the other backward unless there was some means of reversing the movement of one wheel. The statement made (p. 23) on the authority of Dr. Luxenberg, that increasing the diameter of the wheels from 2 feet 6 inches up to 5 feet would effect a saving of 40 per cent. in the pull, required confirmation. He thought it must be an exaggeration. Experiments were being carried out by Professor Hele-Shaw with the apparatus provided by the British Association Committee for measuring tractive pull, and he did not think that increase of diameter showed such a large decrease in the pull as was stated by Dr. Luxenberg.

Prof. Ayrton. Professor AYRTON remarked that Colonel Crompton's observations had been directed rather to a contrast between accumulator-cars and horsed vehicles; while he himself had had in mind the subject of the Paper, which was rather a contrast between accumulator-cars and petrol and steam cars. It was stated on p. 30, in reference to the cost of running electric vehicles, "This cost will compare favourably with that for any other kind of self-propelled carriage; and renders electric propulsion on roads, with its advantages already enumerated, more promising than any other system of motor-carriages." He would be glad to know whether Colonel Crompton thought that, including renewals and maintenance, the cost of running accumulators-cars was such as to render them more promising than any other kind of motor-carriage.

Col. Crompton. Colonel CROMPTON replied in the affirmative, observing that he considered electric automobiles had a very good chance, especially under such conditions as would obtain in the case of a private

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family. Supposing, for instance, that the wife desired to do an afternoon's calling, he thought it could be done in an accumulator motor-car at a cheaper rate than the 15*s.* an afternoon charged for a carriage. The car could be driven by the ladies themselves, thereby saving the driver's wages. The saving in wages was much greater than the slight extra running-cost of repairs and electrical energy on the one side, over petrol and repairs on the other. Assuming that a driver received 35*s.* per week, his wages must be divided by the number of times the carriage was taken out, and as it would probably not go out every day, it would be fair to take 6*s.* or 7*s.* for an average day's work. That 6*s.* or 7*s.* would be entirely saved in the case of accumulator-cars. There was no doubt that ladies could drive accumulator-cars; they only had to turn a handle, ring a bell, and start and stop the car, and there was nothing to get out of order: whereas, on the other hand, it could not be said that, as a rule, ladies could be trusted with either petrol cars or steam cars. Col. Crompton.

Mr. P. W. NORTHEY considered that the Paper contained useful data. Such data, however, took a certain amount of time to collect, and in the meantime improvements in electric automobiles were being rapidly made. It was asserted in the Paper, in connection with zinc as a negative electrode in accumulators, that porous pots were necessary. He did not think that was so; because, although such pots had been used on a fairly large scale in one case, he thought they were a source of danger if the zinc, by forming a tree across, could be deposited on the inner side of the pot, against the oxidized lead paste. That gave rise to a serious difficulty, and the cell could not be put right without a great deal of trouble. He found in practice that a large space was necessary between the positive and zinc negative electrodes. With regard to gearing, it was stated that worm-gearing was quite inefficient, and for that reason, and because it was not easily reversible, it was held to be of no account. He quite agreed that nearly all text-books abused worm-gearing as inefficient compared with other gears, and no doubt it had been inefficient at the time of the publication of those text-books; but at the present time such gear was very different from what it had been some years ago. Worm-gearing had now been improved, and was wonderfully efficient compared with the best forms of spur-gearing used in electrical vehicles. So long as the thread, pitch, etc., of the worm were properly designed, nothing better could be desired from the point of view of reversibility. A good test to apply to a carriage with worm-gearing was its power of recuperation. Mr. Northey.

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Mr. Northey. He had compared gears on several cars going downhill under known conditions, and had found the power of recuperation with the tangent screw, if anything, better than with the spur-gearing. If the car was stationary, and it was desired to push it along by hand, there would not be any sticking between the worm-wheel and the worm of such improved gearing. Shunt-wound motors were favoured in the Paper, chiefly for purposes of recuperation, but in practice he thought it was a pity that the great advantages of the series machine should be set aside for the sake of recuperating only. With a series machine the starting-torque must always be greater than it could be under similar conditions with a shunt machine, unless with the latter complicated switches for variously arranging the field-coils were provided; and it was very easy to produce any desired combination with a series winding, either for variable field-strength or for purposes of recuperation. The Author's double-wound armature seemed to be the very thing that was wanted. He thought two motors would be the best means of driving an electrical vehicle, if they were not two separate pieces of apparatus with two sets of gearing; that was to say, if the advantages of the two motors could be obtained in a single machine. He was not at all afraid of the mechanical differential gear; he thought it was one of the most efficient and satisfactory devices on automobiles of standard design; but the great advantage of a double-wound armature or two electrical machines was that if the two halves were thrown into series, a better hill-climber was obtained, than with one motor and half the voltage of the battery, which should be an equivalent thing. He found that all cells in series and one motor was the only combination which was of any use for climbing hills; but it should not be so. On p. 27 the Author, for purposes of calculation, assumed an accumulator weighing 6 cwt. and capable of driving itself 250 miles; he then suggested that if the carriage to carry the accumulator also weighed 6 cwt. it would be propelled 125 miles, or half the distance. But the Author had not taken the varying discharge-rates into account throughout. By the time that battery had been loaded to three times its own weight, the discharge-rate, which might be almost three times as heavy, would have seriously affected the energy-capacity. The development of electric automobiles had been greatly hampered by want of understanding of their limitations. Many comparisons had been made between petrol, steam, and electric cars; but at the present time it was quite useless to make such comparisons. There was nothing to touch an electrical vehicle for strictly

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town work, and nothing to touch a steam or petrol vehicle for touring; but he firmly believed that in the near future a mixed system of electricity and petrol—a system in which a petrol-motor would drive one dynamo on the vehicle, and that machine would be at one time a generator and at another time a motor—would be a very important development of the industry. Colonel Crompton's remarks were extremely encouraging, but Professor Ayrton and Mr. Clarkson had taken a pessimistic view of the situation. He would like to ask how Professor Ayrton would arrive at his tell-tale for indicating the limit of 1·8 volt; because when running along a level road a battery might read 1·9 volt, whereas directly the same battery, a moment or two later, was taken up a hill of 1 in 10, the discharge-rate might be increased fivefold, and the difference of potential be as little as 1·7 volt per cell, which would be a false indication to the driver. With a little experience, the driver of an electric automobile could tell to within a few watt-hours the amount of energy remaining in the battery; if he could not do so he ought to get dismissed. Mr. Northey.

Mr. L. H. Rugg remarked that, as the Author had referred to worm-gearing, he had taken the opportunity of exhibiting on the table a worm-gear which had been successfully employed on the Lanchester petrol car. The gear shown had run several hundred miles. It would be noticed that there was but little wear; in fact, Mr. Lanchester had informed him that a similar gear had run for 10,000 miles with scarcely less efficiency than the one exhibited. The ratio of the worm to the wheel was 5 to 1; the worm was of hard steel, and the worm-wheel of phosphor-bronze. The interesting point was that the angle of the worm was as much as 45°, and with such an angle the worm could be driven backwards without the slightest difficulty. In regard to tractive resistance on roads, he had recently had the permission of the London Road Car Company to make some experiments with a view to ascertain the initial pull required to start one of their vehicles on various surfaces. The results were:—39 lbs. per ton for asphalt; 49½ lbs. per ton for wood-paving; and 104 lbs. per ton for dry macadam. In each case the road had been perfectly level, and the experiment had been conducted under the most favourable conditions. On asphalt which was a trifle greasy the initial starting pull had been found to be nearly 150 lbs. per ton, although the experiments had been conducted on a level road. The vehicle experimented on was an ordinary London Road Car omnibus, weighing 1 ton 18¾ cwt., and fitted with iron tires. Mr. Rugg

Mr. W. Worby Beaumont asked Mr. Rugg to explain the nature Mr. Beaumont.

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Mr. Beaumont. of the dynamometer or apparatus with which he had measured the pull, because the figures mentioned, as to the pull required on wet asphalt compared with dry asphalt, seemed to suggest that the movement of the horses caused sudden jerks which differed from the slower pull when the road was dry; and that would explain to a large extent the wide difference between the 150 lbs. and the 39 lbs. per ton which Mr. Rugg had stated to be required to start the omnibus on dry asphalt.

Mr. Rugg. Mr. RUGG replied that he had made a mistake in giving the figure as 150 lbs.; it should be 79 lbs. In making the experiments the horses had been taken out on each occasion, and the initial pull, which had been put on gradually by three men in each case, had been taken by a graduated spring-balance which belonged to Dr. Kennedy, and which he thought might be taken to be fairly accurate.

Mr. Drake. Mr. BERNARD DRAKE mentioned that, when in New York during the past year, he had been struck with the great preponderance of electric vehicles over petrol vehicles in the streets of that city. Ladies were constantly seen driving their own cars—a thing to which people in England had not been accustomed. The president of the company controlling the chief battery patents, which had been formed into a large Trust, had informed him that accumulator-traction for automobiles was extending rapidly. It was not claimed that the working-cost compared with that of the petrol motor, but on the score of convenience and reliability the electric vehicle was first. In the question of petrol versus electricity, the relative cost of power was a small item compared with the labour. Labour in the States was even more expensive than it was in England; and cars which could be driven by any one, and could be relied upon to make short journeys for shopping or calling purposes without hitch, were those which were finding most favour in New York. With regard to the batteries, he had found that pasted cells of one kind or another were now being chiefly used. He had seen but little difference between the batteries now being made in New York and those which he himself had made, according to Reckenzaun's method, as managing engineer of the Electrical Power Storage Company in 1886. The plates in these cells had been very thin; the active material had been much the same as at present, and the output had compared very favourably with that of the Fulmen battery or any of the other batteries for which figures were given in the Paper. In fact Mr. Reckenzaun appeared to have been altogether before his time. The gears which had been made to his designs at the

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Power Storage Company's works had included a worm-gearing run in oil, as applied to the first tramcars made; and a number of tests made with this gearing had proved it to be highly efficient. In comparing electric cars and petrol cars, the main point was the ease with which the speed could be varied in the electric car. In a petrol car the variation of speed was a mechanical problem which had not yet been satisfactorily solved; whereas in the electrical car it had been worked out, and the speed could be varied with the greatest ease within wide limits. In the petrol car different sets of wheels had to be put into gear, and often the edges of the teeth were destroyed. It was necessary to be careful to get the speed right before changing the gear, otherwise a breakage occurred. The engineer of one of the largest automobile manufacturing companies had remarked that it was a question whether it would not really be worth while to have an engine running continuously and driving a dynamo, and to have two motors to drive the wheels, thus doing away with the gearing and the incessant trouble caused by it. In regard to Professor Ayrton's first point, about constant current *versus* constant voltage for charging, he thought both systems were incorrect, and that an intermediate course would yield a still better result. It was quite true that when batteries were empty they could be charged at a high rate without energy being wasted in producing gas or heat; but as the battery became charged the current required to be diminished to zero in order to get the maximum efficiency; if it was not diminished, heat and gas were generated, showing that energy was being wasted. If, however, batteries were charged at the maximum voltage when empty, the initial current was excessive, and in time the active material would be damaged. Probably the reason why Professor Ayrton had obtained better results with the constant voltage than with the constant current was that he had charged at 20 amperes, and had stopped at 20 amperes as soon as the voltage had risen to 2·55 volts. If he had gone on diminishing from 20 amperes to 15 amperes, 15 amperes to 10 amperes, and so on, he would probably have obtained the same capacity in both cases. With regard to the weight of accumulators, the tendency in America and elsewhere was to use accumulators for only short runs, and not to attempt to run any such distance as 100 miles. If accumulators to run at most 20 to 30 miles were used, the battery was easily carried, and gave quite efficient results; but if accumulators expected to run 100 miles were put into a car, excessive weight would have to be carried, which would be expensive to maintain: in addition to which the motors and framing would become clumsy. For electric auto-

Mr. Drake.

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Mr. Drake. mobiles, under the existing conditions, he therefore recommended that they should be of light weight for short runs, and be confined to town use, wherein they would do good service.

Dr. Kennedy. Dr. ALEX. B. W. KENNEDY remarked that, as a member of the public rather than as an engineer, he would like to mention a few points which had particularly struck him. He was in agreement with what Mr. Drake and other speakers had said, and was glad to emphasize the point that, for town work, electric cars were so much more comfortable than other kinds that their adoption on an extensive scale was by no means entirely a question of cost. He hoped the cost would be reduced later on; but he did not think that question arose at the present stage, if the price had been brought down to a reasonable figure. He was not quite sure he could say that it had; but, if not, he felt sure it would be in time. In the last column but one of Table V. the Author had given a price which worked out to a total cost of 14*s.* per day. That, he was afraid, was not in agreement with the cost of running an electric car to an ordinary member of the public at the present time. Perhaps the figure quoted would shortly represent the price at which the car could be run, and he hoped the Paper would hasten the advent of that happy time; but he thought it was worth putting on record in the discussion that so far as he knew, an electric carriage—say a landau to carry three or four persons—cost £600 or £700, and unless the owner agreed to keep it himself and took the responsibility of the batteries, he had to pay about £200 a year—he believed that was the figure quoted by one of the companies for its maintenance; in addition to which he had to pay his own driver. At that rate the car cost about 24*s.* per day. Even that sum had not been sufficient, and was not sufficient, to deter many people from running such a car rather than a pair of horses. He had no doubt whatever that, for town work especially, electrically-driven cars would be more and more used, and become more and more popular. He entirely agreed with Mr. Drake that at present the question of running electrical cars for 100 miles need not be considered. Perhaps he ought to say that he was not entirely disinterested in the matter, for the extensive use of electrical vehicles would, as Colonel Crompton had remarked, be an excellent thing for electric-supply companies; but he did not doubt that the time would come when they would be largely used.

Sir Frederick Bramwell. SIR FREDERICK BRAMWELL, Bart., Past-President, mentioned that when he had kept a pair-horse landau in London he had kept accounts, and thus he knew exactly what it had cost, after making

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every allowance for stable, rent, one man's wages, and renewal of the carriage in perpetuity. He would always remember the figure because it was exactly £1 per day—as many pounds in the year as there were days. Sir Frederick Bramwell.

The AUTHOR in reply pointed out that Professor Ayrton's "four hundred full discharges" (p. 47) should be forty full discharges, there being an error in his deductions. Colonel Crompton had taken some exception to the watt-hours per ton-mile given in Table III. The figures had been gathered from published results of the trials; and, taking into account the different constructions, some vehicles with roller bearings and others without, and the differences in the tractive resistance at different times and on various roads, the Author believed the results could be taken as reliable. With this explanation, it would be easy to appreciate the reasons for the differences between the 230 watt-hours per ton-mile given by Professor Ayrton for the London Electric Cab Company's vehicles, and the 50 watt-hours and 86 watt-hours per ton-mile given in the Paper for vastly improved and much lighter vehicles. Mr. Fliess in some trials in New York, under exceptionally favourable conditions, had obtained a result of only 26 watt-hours per ton-mile, which was about half that anticipated by the Author. Mr. Northey's statement as to the efficiency of modern worm-gearing, which had been corroborated by Mr. Rugg, was most instructive, and met the Author's objections. He was much indebted to all those who had taken part in the discussion. He considered that Colonel Crompton's and Mr. Drake's championship of the electric automobile and their remarks and explanations fully answered the criticisms of Professor Ayrton and Mr. Clarkson; while all had added to the Paper and had materially increased the knowledge of its special subject. The Author.

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Correspondence.

Mr. Joly. Mr. HENRI L. JOLY remarked that he could not agree with the statement that abroad makers of electric vehicles were directly helped by government subsidies; he did not think any such subsidies had ever been granted. Orders based upon competitive tests, or on awards at exhibitions, could not be called subsidies. With respect to the $Zn/ZnSO_4/PbO_2$ cell, it should be stated that, however tempting the high electromotive force of this combination might appear, all practical attempts had proved failures; and all future attempts were doomed to the same fate unless some means were found to prevent the re-dissolution of the deposited zinc in the acid electrolyte on open circuit. It was unnecessary to dwell at length upon the impossibility of relying upon a sound zinc deposit, the molecules of which could, like the material in the $Pb/H_2SO_4/PbO_2$ cell, retain their respective positions and work at a regular pace, the local action troubles being much more considerable in the zinc cell. Another great obstacle resided in the high rate of charge which was needed to obtain a solid deposit of zinc—not muddy or spongy—a rate altogether fatal to light pasted positives, which, when submitted to such treatment, dropped to pieces in a very short time. As to charging batteries, the safest course was now generally recognised to be the graded rate, with the intensity of the charging-current diminishing towards the end of charge so as to avoid useless and even dangerous gassing. With regard to the Tables on pp. 10 and 11, the conditions of the tests were widely different; no doubt the figures quoted on p. 10 were obtained on discharging cells at a constant current; while in the Automobile Club tests the rate of discharge had varied according to a certain fixed programme stated in the report, reaching at times, and for short periods, 100 amperes. The changes of rate had been obtained continuously and automatically by means of a very ingenious time-switch, so as to secure conditions somewhat similar to those which obtained in actual practice. It was therefore impossible to compare the two Tables. It was unfortunate that the Author had not given the rates of discharge, and also the weights of cells referred to on p. 10. It was known that, as the rate of discharge increased, both the yield in ampere-hours and

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the average voltage dropped, according to a law stated by Peukert,[1] the resultant watt-hour capacity varying accordingly. Peukert's coefficient varied with the type of cell,[2] and the following example would show how much better a cell could be made to appear, in comparison with another of equal weight, if the rates of discharge were different. A certain cell used by Mr. Joly gave, at the 15-hour rate, 16·7 ampere-hours per kilogram 7·6 ampere-hours per pound of cell complete, while at the 3-hour rate the capacity was only 11·5 ampere-hours per kilogram (5·2 ampere-hours per pound). This particular kind of cell, due to Contal, had shown itself to be remarkably efficient, and the life of the positive plates, under conditions of daily work in an electric victoria, was about 1 year. After 9 months' use, the drop in capacity, as shown by his tests, was less than 10 per cent. Recent improvements in accumulators had been especially directed towards cheapness and extended life of the mechanically weak plates. As to capacity, Reynier stated that about 1886 Faure made a cell the weight of which was at the rate of 25·5 kilograms per horse-power-hour, a figure which came within 0·66 lb. of the best results of the present day. The Riker four-pole motors of 1898 were very similar to those used in England by Reckenzaun over 12 years ago, having a steel yoke and four poles, two wound and two consequent. One of the lightest motors extant, if not the lightest, was the Contal-Gasnier, the 5-HP. size of which weighed barely 165 lbs. The method of connecting the batteries in parallel in order to alter the speed of the vehicle, was in his opinion objectionable though simple, because the differences in resistance of the various circuits thus formed cause unequal rates of discharge in the divided battery, and accordingly did not give the cells a chance of working properly. The benefit of recuperation was not so conspicuous in the case of road traction as in that of street cars or tramways; an obliging downward slope, 3 miles long, yielding a supply of energy by the action of gravity, was rarely met with; even with such a lucky occurrence, the chances were that the battery would have to yield enough current to manage equivalent or perhaps steeper hills on the return journey. The real advantage lay in the raising of the potential difference by even a very short re-charge. In his report upon the electric-vehicle trials of 1900, Dr. Kallmann, of Berlin, gave the power it was advisable to provide as 1 kilowatt per ton. He thought this figure was too

Mr. Joly.

[1] Minutes of Proceedings Inst. C.E., vol. cxxx. p. 383.

[2] See *L'Éclairage Électrique* (Paris), vol. xv. p. 143.

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Mr. Joly. small. He was sorry the optimistic figures put forward by the Author on p. 30 (50 watt-hours per ton-mile at a cost of 0·1*d.*) seem impossible at present. Although, in the experiments carried out by Fliess in Manhattan, so low a figure as 20·7 watt-hours per ton-mile seemed to have been obtained, the average consumption of that particular wagon was 78·3 watt-hours per ton-mile, which was the lowest of the whole series of tests. On the Continent 70 watt-hours per ton-kilometre (112 watt-hours per ton-mile) was considered a good figure in actual work. Mr. Muhlberg had made in 1898 some tests in Berlin on dry and level asphalt roads with a tractive coefficient stated to be 15 kilograms (33 lbs.) per ton. The results were:

Single-reduction spur-gear	61	watt-hours per ton-kilometre	{	(98 watt-hours per ton-mile.)	
Double-reduction	„	66	„	„	„	(105	„	„	)
Chain drive	„	69	„	„	„	(110	„	„	)

The average was 65 watt-hours per ton-kilometre. He believed the vehicle used had had ball-bearings. The best figure in Dr. Kallmann's report already alluded to was also 61 watt-hours per ton-kilometre, or nearly 100 watt-hours per ton-mile. With regard to charging, it was necessary to point out that when central stations were equipped with continuous-current machines at more than 120 volts, the charging was rendered expensive by the use of motor-generators or resistances, and the cost of current became easily double the price per unit paid to the supply company. The late Electric Cab Company had found this out when transforming cheap alternating current at the beginning of its unfortunate career. Now, with the Nodon valve, and, he hoped, with that promising invention the Cooper-Hewitt converter, alternating-current supply should cease to be the nightmare of the user of accumulators. He feared that in the matter of cost the Author had let his enthusiasm carry him too far. The data available in regard to the cost of other mechanically-propelled vehicles was scanty, and some of the statements were quite unreliable. He was greatly surprised to see the cost of a London cab put down at only 15*s.* 4*d.* per day. The "Compagnie Générale" in Paris, with a unique and thorough organization, controlling thousands of vehicles, had given, in 1898, the following figure: 19·26 francs (16*s.* 4*d.*) per cab per day. The 1898 "Concours de Fiacres" in Paris had given for the electric cab, with current at 1½*d.* per kilowatt-hour, 20·22 francs (17*s.* 2*d.*). Ducasse (Cie. des Voitures electromobiles), with a remarkably equipped business,

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came a bad third with 23 francs per cab per day (19*s.* 7*d.*). The Paris electric cabs were practically working at this last figure, and he knew that when the London cabs were working with sixteen vehicles the cost per week per cab (directors' fees not included) was £9 12*s.* 11*d.*, or about 32*s.* per cab per day, the takings not exceeding 23*s.* per cab per day. The cost of maintenance of accumulators was given by Ducasse at 7 centimes per kilometre-car, that of tires at 6 centimes per kilometre-car. At the last meeting of the "Association Française pour l'Avancement des Sciences" (Montauban, 1902) various interesting Papers had been read bearing on the subject. Mr. Jumau stated that the average cost of maintenance of cells came to about 0·043 franc per tonne-kilometre (0·67*d.* per ton-mile). Although a devoted exponent of electric traction, Mr. Joly could not be blind to the sorrowful example of all who had attempted to run public services of electric cabs on the basis of figures assumed or estimated to be as encouraging as those given in Table V. In Chicago, with 109 vehicles and an outlay of $643,588, the cost of working over 4½ months had been $265,885, the takings $137,106, or a loss of $8·75 (£1 15*s.*) per vehicle per day. The tale of Boston, the streets of which were by no means as smooth or level as the avenues of Chicago, was just as appalling. In 6 months 245 wagons had earned $95,310, the running-expenses had been $211,965, the capital outlay $769,036, the loss per vehicle per day $2·64 (10*s.* 8*d.*). With regard to the income electric vehicles brought to central stations, the Secteur de Clichy, which supplied only a part of Paris, had reported to its shareholders the receipt of £3,000 to £4,000 a year from this source alone, during the past 4 years. Was it not time for central-station engineers to pay attention to these figures? He believed that electric carriages maintained in large numbers on the "garage" system, as in New York and Paris, and by some London undertakings, would ultimately prove successful. Mr. Joly.

Mr. J. N. Shoolbred remarked that for a considerable extension in the use of electric automobiles two things were necessary—first, a lighter and improved arrangement of storage-battery, and secondly, a much more extended system of charging-stations, and of facilities for using those stations. The first matter might fairly be left to the actual manufacturers of storage-batteries, seeing the inducement held out to them by such improvements; while the second was a matter to which he had paid much attention for some years past, not only for automobile traffic—which was a comparatively recent question — but for providing electrical energy for the Mr. Shoolbred.

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Mr. Shoolbred. many industrial purposes to which that form of power was being applied. If, for example, in the streets, where there was a hydrant, an electrical stand-post were also placed, a small electrically-driven pump would prove a much lighter and more easily handled fire-apparatus than the cumbrous steam fire-engine. The former would be got to work much more quickly and readily than the latter, especially if all large public buildings were supplied with such an electric fire-engine. This example was merely one of the many advantages which would follow in a large town from an increase in the number of points at which a supply of electrical energy was available. Owing to the general acceptance of the 500-volt low-pressure limit of the Board of Trade for both lighting and traction supplies, more especially where continuous current was used, there ought to be but little difficulty, thanks to this uniformity, in augmenting largely the number of charging-stations. At present there were in England two hundred and twenty continuous-current low-pressure, and eighty alternating-current generating-stations, for electric lighting alone. In stations where alternating current was in use, the conversion thereof into continuous current by means of rotary converters, or by the Hewitt static converter, which had recently been added to the list of converters, there would seem to be means by which the small charges of continuous current required by electric automobiles could also be obtained. Nor need the comparatively low pressure of, say, 80 volts, required for the automobile, present any difficulty. For it had been a not uncommon thing of recent years for private storage-batteries to be presented for re-charging at a 500-volt continuous-current station. The rapid extension of electric tramways, and light railways along the main roads, would facilitate enormously the multiplication of charging points for the use of, among other things, electric automobiles. As he had recently pointed out in the Correspondence on the Paper by Messrs. Mordey and Jenkin,[1] the coming tendency was to use electricity as the common motive power for all methods of transport. That Paper merely accentuated the advantages which followed from uniformity, whether in electrical pressure, or in the road-gauge of railways and tramways, or in other matters. The results of such uniformity must tend to cheapen the cost of transport generally. A striking indication of the tendency to bring the several modes of transport more into

[1] Minutes of Proceedings Inst. C.E., vol. cxlix., p. 188.

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uniformity had been furnished recently. The Liverpool Corporation, themselves the owners of an extensive system of electric trams having at present a daily total tramcar-mileage of about 37,000 miles, acting in conjunction with the South Lancashire tramways, whose system connected not merely with the Liverpool Corporation lines, but also with others inland, where cotton mills and large industrial works abounded, had applied to the Mersey Docks and Harbour Board for permission to take goods wagons into the dock estate and alongside of the vessels themselves, with the object of conveying the goods and other freight from the ship direct to the mills or other works some distance up the country, and thus avoiding any further change of transport, and at the same time dispensing with the vexatious railway terminal charges. Subsequently, in order to show the practicability of this interchange of traffic, a run with passengers had been made from Liverpool to Bolton. A service of goods transport of this character—one which could readily be carried out in other places—presented a serious matter for the consideration of the railway companies; while at the same time it accentuated the wisdom of the far-sighted views, which had already been expressed by some general managers of railways in England, that co-operation with, and not opposition to, electric tramways would be the proper policy for the railways themselves to adopt. Mr. Shoolbred.

The Author, in reply, remarked that Mr. Joly appeared to blow hot and cold at the same time, and his criticism was not quite intelligible on that account. While he questioned the Author's figures of 50 watt-hours per ton-mile on a good hard level road, he quoted Fliess, with a figure in one instance of only 20·7 watt-hours per ton-mile. The Author considered that his experience on many trials and long runs justified him in giving the figure of 50 watt-hours per ton-mile. The efficiency of the electric motor, the comparative output and weight of the battery, the arrangement of circuits and commutation to avoid loss in resistances, the mechanical construction of the car body, its weight in proportion to its load capacity, the even distribution of the total weight of load and battery over the wheels, and the use of roller-bearings everywhere, were all factors governing the resulting all-round efficiency and tractive resistance. With regard to Mr. Joly's criticism of the Tables given on pp. 10 and 11, he would point out that the results given on p. 10 were the highest possible from the manufacturers' own figures, and, of course, must not be taken as the practical average output. He had obtained 12 watt-hours per complete cell from the Rosenthal battery, on a run of 53 miles The Author.

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The Author. with the Car No. 3 in Table III. The results given in the Table on p. 10 were those obtained by the Automobile Club of France in 1899 under extreme and exacting conditions, and they were not given for comparison. The working costs of various methods of propulsion, given in Table V., were in detail to allow criticism; they had been prepared with great care, as far as the limited practice would allow; and he was of opinion that they were reliable. The figure given for the total cost of a London cab per day, namely 15*s.* 4*d.*, was a fair average.

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20 January, 1903.

JOHN CLARKE HAWKSHAW, M.A., President,
in the Chair.

The Discussion upon the Paper on "Electric Automobiles," by Mr. H. F. Joel, occupied the evening.

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27 January, 1903.

JOHN CLARKE HAWKSHAW, M.A., President, in the Chair.

(*Paper No. 3361.*)

"The Nile Reservoir, Assuan."

By MAURICE FITZMAURICE, C.M.G., B.A.I., M. Inst. C.E.

WITH the exception of the northern margin of the Delta along the coast of the Mediterranean, Egypt (*Fig. 1*) is a country practically without rain, and is absolutely dependent on the Nile for its water-supply. The volume of water in the river during the winter months is much larger than is required for the needs of the country, and during the summer months the supply is not nearly sufficient. It is therefore not surprising that the construction of reservoirs which should enable part of the surplus winter water to be stored for use during the summer months has been a burning question in Egypt for many years.

The White Nile, coming from the great lakes of Central Africa and fed on the way by the Gazelle and Sobat rivers, joins at Khartum the Blue Nile, which comes from the Abyssinian mountains. From the junction northward the river is known as the Nile; and it receives its only tributary, the Atbara, at a distance of 320 kilometres[1] (200 miles) north of Khartum. The Nile enters Egypt at Assuan, 1,800 kilometres (1,125 miles) north of Khartum and 1,200 kilometres (750 miles) from the Mediterranean; and the ancient Nilometer built here is the standard gauge as regards the state of the river. The first rise of the level of the water in the river at Assuan appears about the end of May; and there is then a continuous slow rise until the end of June, after which date it becomes more rapid (Fig. 5, Plate 1). The first part of the rise is due to flood-water coming down the White Nile; but by the end of June the floods coming down the Blue Nile and

[1] In the original most of the dimensions are in metric measures: for convenience, approximate English equivalents have been added in brackets.

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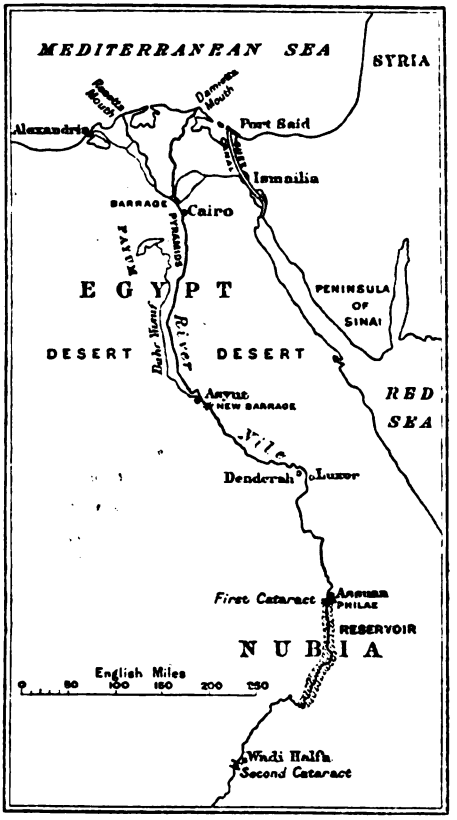
the Atbara are felt at Assuan. During July the two latter rivers are rising rapidly, and during August and September the Nile is in full flood at Assuan, and the water is heavily charged with the rich fertilizing mud which the Atbara and the Blue Nile bring down from the Abyssinian hills. From the beginning of the flood at Assuan, at the end of May, until the maximum is attained,

Fig. 1.



about the 10th September, the discharge of the river rises in an average year from about 400 cubic metres to 10,000 cubic metres (14,000 cubic feet to 353,000 cubic feet) per second. The maximum flood-discharge of the White Nile is about 4,500 cubic metres (159,000 cubic feet), of the Blue Nile 5,500 cubic metres (194,000 cubic feet), and of the Atbara 3,500 cubic metres (124,000 cubic feet), per second; but, as the White Nile does not attain its

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maximum until about a month later than the other two rivers, the maximum discharge at Assuan is less than the aggregate maxima of the three rivers.

There are two systems of irrigation in Egypt—basin irrigation and perennial irrigation. In the basin system the waters of the Nile when in flood are turned on to the land, which for this purpose is divided into large areas called basins, and there the valuable fertilizing mud is deposited. The water remains on the land to an average depth of about 1·50 metre (5 feet) for about 40 days, and is then turned into the river again. Under this system one crop is obtained in the year. With the perennial system the land is irrigated all the year round; two crops are obtained every year from a large portion of the land; and the crops are more valuable than the "basin" crops. With a low-Nile discharge during the summer months, however, there is not sufficient water for even the present area under perennial irrigation; and consequently some of the land gets no water, and some an insufficient supply.

The object of the reservoir at Assuan is to supplement the discharge of the Nile during the summer months of May, June and July, by discharging the water which has been stored during the winter months: thus ensuring a sufficient supply of water to the land at present under perennial irrigation, and enabling an increase to be made in the area of land irrigated on this system. This will allow a large increase in the land under the valuable crops of sugar-cane and cotton.

Historical.

The first systematic study of the question where reservoirs could be made, of the best method of making them, and of the amount of water obtainable, was commenced in 1890. Before that date, several suggestions for reservoirs had been brought forward at different times; but it was not until 1890 that the Egyptian Government, at the request of Sir Colin Scott-Moncrieff, K.C.S.I., Assoc. Inst. C.E., decided to study the whole question anew; and Mr. Willcocks (now Sir William Willcocks, K.C.M.G.), M. Inst. C.E., was appointed director-general of the study.

In his report,[1] made at the end of 1893, after more than 3 years' careful study of the valley of the Nile and the depressions in the desert north of Wadi Halfa, Mr. Willcocks

[1] "Report on Perennial Irrigation and Flood Protection for Egypt." Cairo, 1894.

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dealt with four sites for reservoirs, three in the Nile valley and one in the Wadi Rayan depression in the desert, about 30 kilometres (19 miles) west of the Nile valley, a site originally proposed by Mr. Cope Whitehouse. The report was accompanied by plans and estimates for the works necessary at each place. Mr. Willcocks considered the reservoir which could be formed by a masonry dam at the head of the first cataract on the Nile, at Assuan, to be the best of the different schemes submitted. This view was endorsed by Sir William Garstin, G.C.M.G., Under Secretary of State for the Public Works Department; but owing to the magnitude of the work he proposed that the Egyptian Government should appoint a Commission of three of the most eminent engineers in Europe, for the purpose of considering the several schemes and advising the Egyptian Government as to which of them should be adopted.

The Commission was accordingly appointed, and consisted of Sir Benjamin Baker, K.C.B., K.C.M.G., Past-President Inst. C.E., Mr. Giacomo Torricelli and Mr. Auguste Boulé. These gentlemen spent 3 months in Egypt, examining all the proposed sites, and going through the plans and projects placed before them by the Egyptian Government. They reported:—

1. That the valley of the Nile was more suitable than the Wadi Rayan depression for the formation of a reservoir.

2. That the reservoir-dam should, as proposed by Mr. Willcocks, be pierced by numerous undersluices regulated by gates, capable of passing the whole volume of the Nile in flood. This was necessary to prevent any deposit of silt in the reservoir during flood.

3. That there was no insurmountable difficulty in constructing such a dam and ensuring its permanent stability.

Two members of the Commission, Sir Benjamin Baker and Mr. Torricelli, selected, from among the sites for a dam submitted to them by the Egyptian Government, the head of the Assuan cataract as the only place on the river north of Wadi Halfa where the following conditions, which they considered necessary, could be obtained, namely:—

(*a*) A solid rock foundation.

(*b*) A wide section of river, so that the openings might not be close together. This condition would cause the dam to approach as nearly as possible to a solid one, and would permit the water issuing from the sluices to be well scattered and evenly distributed.

(*c*) A shallow depth of water, so that the total height of dam above the foundations might be as small as possible.

Mr. Boulé made no selection of a site for a dam.

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The same two Commissioners also recommended alterations in the Government design for a dam at this place. All the modifications were in the direction of making the design approach more closely to that of a solid dam, and of increasing its stability.

As a result of the decision of the Commission, it was decided to construct a dam to hold up water to Reduced Level[1] 114·00 (374·00) at the site recommended by Mr. Willcocks, namely, across the head of the Assuan cataract, to the north of the island of Philae. The maximum head on the dam would be 26 metres (85 feet), and the volume of water stored would be about 2,500 million cubic metres (88,300 million cubic feet).

The construction of a dam raising the water-level to the height stated involved the submersion of the temples on the island of Philae; and strong protests against the scheme were lodged by the principal archæological societies of Europe. The project was consequently reconsidered, and Mr. Willcocks prepared revised designs for a dam to hold up water to R.L. 106·00 (348·00), adopting the different modifications proposed by Sir Benjamin Baker and Mr. Torricelli. These designs were ready early in 1895, but owing to financial reasons it was not possible to commence the work at that time.

The probable effect on the health of the inhabitants of Egypt from the storage of such a large quantity of water; the question whether the water thus stored would deteriorate; and the effect of the subtraction of a large quantity of water from the usual discharge of the Nile at certain periods of the year; were all subjects of anxious consideration by the Egyptian Government. The importance of these matters in a country where, as already stated, there is practically no rain, and where the Nile is the sole source of water-supply for all purposes, is at once apparent. A special cause of possible deterioration in the stored water is due to the fact that, for a short time every year, generally in the month of June, when the Nile is beginning to rise and before the reservoir is emptied, the water of the river is polluted with decaying vegetable matter, brought down by the first flush of the flood on the White Nile, from the swamps south of Fashoda. This so-called "green water" sometimes causes the river to assume a very unpleasant character, as regards colour, taste and smell: at other times the green-water period passes almost unnoticed. No

[1] All reduced levels (R. L.) refer to heights in metres above mean level of the Mediterranean Sea. The equivalents in feet are given in brackets.

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disease of any kind, however, has been traced as being due to this water. In his original report on reservoirs, Mr. Willcocks did not fail to draw the attention of the authorities to these points; and one of the problems which he put forward in connection with the reservoirs was "the effects on the quality of the water when the new changes are introduced." He expressed his opinion clearly in the following words[1]:—"The Nubian reservoirs will be filled in November and December after a low flood and in December and January after a high flood. At this time of the year the Nile water is very pure, and as it will be perpetually flowing with a depth of from 10 to 30 metres, it will consequently remain pure. The effect of this quantity of wholesome water on the green water of the Nile in June and July of a low summer will be to dilute it and considerably improve it. The Nubian deserts are quite free from impure and harmful salts of all kinds. The numbers of reservoirs in the world which store water and which have stored it for hundreds of years, without in any way hurting it, are a perfect guarantee for any reservoirs constructed in the bed of the Nile." Sir William Garstin shared Mr. Willcocks's views on the matter, but asked Sir John Rogers, K.C.M.G., the head of the sanitary department of the Egyptian Government, to look into the question; and in his report, where he was careful to avoid what he called the temptation of irrigation-engineers to reduce all results to cotton or sugar-cane, regardless of human life, Sir John did not foresee any danger to public health from the construction of the reservoir. The matter was finally dealt with by the International Commission already referred to, and it may not be out of place to put on record the conclusions arrived at. The Commission, in fact, accepted the views of Sir John Rogers, which were the following:—

(*a*) The summer discharge of the Nile, down-stream of the reservoir, will be augmented from the 5th May to the 25th July, and this will constitute a gain to the country from a sanitary point of view.

(*b*) The winter discharge of the river during the filling of the reservoir will be diminished, but not to an extent sufficient to prejudice the public health.

(*c*) The quality of the water in the Nile and in the reservoir will gradually deteriorate as the summer advances, but this deterioration will be less than that which takes place now that there is no reservoir.

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[1] "Report," etc., p. 46.

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(*d*) Special precautions should be taken to prevent the pollution of the reservoir, and the removal of cemeteries is one of the precautions which should be adopted.

On the 21st February, 1898, a contract was signed by H. E. Hussein Fakhry Pasha (now Sir Hussein Fakhry Pasha, K.C.M.G.), Minister of Public Works, representing the Egyptian Government, and Messrs. John Aird and Company, by which the latter undertook to construct the dam at Assuan for £1,500,000 and the weir at Asyut for £500,000, a total of £2,000,000; payment to be made by sixty half-yearly instalments of £78,613, commencing on the 1st July, 1903, the date fixed for the completion of the work. By this arrangement the Egyptian Government, during the progress of the work, paid no money in cash, except as regards excess quantities over the contract quantities, but issued bonds for £4,716,780 payable over a term of 30 years after the dam was finished. At the same time a financial arrangement was entered into with Sir Ernest Cassel, K.C.M.G., by which he took over the bonds, and the contractors were paid in cash on the usual monthly certificates.

The sub-contract for the ironwork required for sluices, lock-gates, etc., amounting to over £300,000, was obtained by Messrs. Ransomes & Rapier.

At the time of the signing of the contract the late Mr. W. J. Wilson, M. Inst. C.E., had succeeded Mr. Willcocks as Director-General of Reservoirs, and on Mr. Wilson's death in August, 1900, Mr. A. L. Webb, C.M.G., M. Inst. C.E., took his place. Sir Benjamin Baker was appointed Consulting Engineer.

Geological.

As already stated, the dam crosses the Nile valley at the head of the Assuan cataract, where the width of the valley is about 2,000 metres (2,185 yards). The rocks at the cataract are highly-crushed and faulted igneous rocks of Archæan age. The most abundant rock, and practically the only one which was exposed until excavation was begun, is a coarse-grained red granite. In consequence of its acid nature, this rock, on which the greater part of the dam is built, has suffered but little from crushing and weathering. In the beds of the channels of the river and under the alluvium on the east bank, the granite alternates irregularly with dioritic and syenitic rocks of dark colour; and these, on account of their more basic composition, have undergone great decomposition under

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the combined agency of crushing and water-action; they often form schistose micaceous masses soft enough to be taken out with a pick. Naturally the river, in choosing the path of least resistance, has cut its channels through the softer rocks, leaving the hard granite as islands. Dykes of basalt, quartzite and pegmatite cut the axis of the dam transversely in many places.

Description of Reservoir.

The dam extends across the valley in a straight line, crossing the five summer channels of the river. When the Nile is in flood the width of the waterway is about 1,400 metres (1,530 yards), with a maximum depth of 17 metres (56 feet); but for about 8 months of the year the river is confined to the five channels mentioned (Figs. 3 and 4, Plate 1). The line chosen gave, as far as could be ascertained before excavating, a probability of good rock for the whole length of the dam; the valley was wide enough to allow the construction of sufficient sluices to give a very free waterway to the Nile in flood; the depth of water in the channels was not excessive; and each channel could be dealt with separately if necessary.

As already mentioned, the dam is to hold up water to the level of 106 metres (348 feet) above mean sea-level; and the lowest level of water on the down-stream side is R.L. 86·00 (282·00). The greatest head of water on the dam will therefore be 20 metres (65·6 feet). The storage-capacity is estimated at 1,065 million cubic metres (37,612 million cubic feet). On account of the large amount of silt brought down by the Nile when in full flood precautions have to be taken to prevent the silting up of any reservoir formed in the Nile valley. At Assuan no attempt is made to store water until the river is practically free from silt, which occurs about 3 months after the Nile is in full flood. Sufficient sluices are provided in the dam to allow the Nile to pass through when in flood without any appreciable diminution in velocity, and consequently without causing any deposit of silt in the reservoir. No water is allowed to flow over the dam. In an average year the Nile flood reaches its maximum at Assuan early in September; by the 1st December it has fallen about 4·5 metres (15 feet), and the water, which has been heavily charged with silt during the flood, is almost clear again. The reservoir will therefore be filled between December and March, when there is practically no silt in the Nile water, and when there is more water in the river than is required for irrigation; and it will be

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discharged during the summer months of May, June and July, when water is badly wanted, particularly for the cotton crop.

The Assuan gauge is fixed at the foot of the cataract, opposite the town of Assuan, and there is another gauge fixed on the island of Philae, above the cataract. As the dam is at the head of the cataract, the Philae gauge recorded the water-levels which had to be dealt with during the progress of the works. The total fall in water-level from Philae to Assuan is 5 metres (16·4 feet); and when there is no obstruction in the river, this difference is practically constant throughout the year. The mean low Nile at Philae is R.L. 90·00 (295·00) and mean high Nile is R.L. 98·00 (321·50). The river therefore rises 8 metres (26·25 feet) between low Nile and flood Nile. As the high-water level in the reservoir will be R.L. 106·00 (348·00) there will be a rise of water up-stream of the dam of 16 metres (52·5 feet) above low Nile or 8 metres (26·25 feet) above high Nile. The extent to which the reservoir will extend southward in the valley of the Nile depends on the slope which the water takes up-stream of the dam when the reservoir is full. It is extremely difficult to say what this slope will be. The present water-gradient south of the dam in flood is about 1 in 16,000, and assuming this slope to be flattened to 1 in 32,000 when the reservoir is full, the effect of the reservoir will be felt for 225 kilometres (140 miles) south of the dam. The Nile valley in Nubia, in which the reservoir will be situated, is narrow, and the cultivated area small. In many places the hills, destitute of any cultivation, come down to the river's edge; and in most places the cultivated land is limited to a narrow strip not more than 200 to 300 metres (650 to 1,000 feet) wide.

From the elevation of the dam (Fig. 2, Plate 1) it will be seen that the sluices, of which there are one hundred and eighty in all, are arranged at four different levels, namely, R.L. 100·00 (328·00), 96·00 (315·00), 92·00 (301·75) and 87·50 (287·00). When the reservoir is being emptied, the highest sluices which will discharge the required amount are used, so that the velocity of the water through the sluices may be kept as low as possible. The maximum head under which water will be discharged through a sluice will be 9 metres (29·5 feet), which gives a velocity of 10·5 metres (34·4 feet) per second. All the sluices which will be used for regulating the water while the reservoir is being filled and emptied are fitted with Stoney roller gates (Fig. 13, Plate 2). There are one hundred and thirty of these regulating sluices, of which one hundred are 7 metres (22·96 feet) high by 2 metres (6·56 feet) wide, and thirty are 3·5 metres (11·48 feet) high by 2 metres

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(6·56 feet) wide. The remaining fifty sluices are required for giving sufficient waterway to the Nile when in flood, and for avoiding any diminution in the velocity of the current, which would cause deposition of silt; after the flood has passed, they are shut until the reservoir is emptied and it is necessary to raise them for the next flood. As, therefore, they are not lowered or raised under a large head of water, they are made as ordinary sliding gates. A hand-power crab for lowering and raising the gates is fixed on the roadway of the dam over each sluice.

The Author does not refer to the details of the sluices, as they are dealt with in the Paper[1] by Mr. Wilfrid Stokes. The same applies to the details of the lock-gates.

If an average year is considered, the following is approximately the procedure which will be adopted. About the 5th July, all the sluices are fully open, and the Nile is then rising rapidly (Fig. 6, Plate 1). At the end of July, the discharge of the Nile is 4,500 cubic metres (159,000 cubic feet) per second (Fig. 7, Plate 1); and this will be discharged through the sluices at R.L. 87·50 (287·00) and R.L. 92·00 (301·75) with a velocity of about 3½ metres (11½ feet) per second, and under a head of 1 metre (3·28 feet). At the end of August, or early in September, the discharge of the river is nearly 10,000 metres (353,000 cubic feet) per second; and this will be discharged through the sluices at R.L.'s 87·50, 92·00 and 96·00 (287·00, 301·75 and 315·00), at a velocity of nearly 5 metres (16·4 feet) per second, and under a head of about 2 metres (6·56 feet). The Nile now falls gradually, and the amount of silt in the water, which is a maximum in August, quickly diminishes. On the 1st December, the first of the sliding gates at R.L. 92·00 (301·75) is lowered. The water-level has now fallen to about R.L. 94·00 (308·50), and the discharge is 2,500 cubic metres (88,300 cubic feet) per second. When the water-level is R.L. 94·00 (308·50), only a small fraction of the discharge is going through the fifty sluices with ordinary sliding gates at R.L. 92·00 (301·75), as the sluices at R.L. 87·50 (287·00) carry nearly all the flow. The gates of the fifty sluices at R.L. 92·00 (301·75) may therefore be lowered almost together, without causing any appreciable backing-up of the water. After the fifty sliding gates are lowered, the sixty-five gates with rollers at R.L. 87·50 (287·00) are gradually shut; and when these have been completely closed, the twenty-five roller sluices at R.L. 92·00 (301·75) are lowered gradually. By the time these twenty

[1] *Post*, p. 108.

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five gates are down, say early in February, the water-level in the reservoir will have reached R.L. 103·00 (338·00); and the water passing down the river will be discharging through the sluices at R.L. 96·00 and 100·00 (315·00 and 328·00), which, with the reservoir-level at 103·00 (338·00), are capable of discharging 1,450 cubic metres (51,200 cubic feet) per second, or rather more than the volume of water actually passing down. The sluices at R.L. 96·00 (315·00) will now be closed gradually, and by the end of February the reservoir will be full, the water-level being at R.L. 106·00 (348·00): the discharge of the river at this date is about 1,150 cubic metres (40,600 cubic feet) per second. While the reservoir is kept full up to this level the surplus water flowing into it from the south is passed on through the twenty-two fully opened sluices at R.L. 100·00 (328·00), and the eighteen partly opened sluices at R.L. 96·00 (315·00). As the discharge of the river diminishes, the sluices at R.L. 96·00 (315·00) are closed, and early in March the sluices at R.L. 100·00 (328·00) will alone be open. As the discharge still diminishes, some of the sluices at R.L. 100·00 (328·00) are gradually lowered, so that no more than the actual discharge of the river, after making good any evaporation in the reservoir, is allowed to pass through, and the reservoir is kept at R.L. 106·00 (348·00). The area for discharge through the sluices at R.L. 100·00 (328·00) is gradually diminished until, about the beginning of May, the discharge of the river has fallen to 500 cubic metres (17,650 cubic feet), and these sluices are only about half open. When the river-discharge has fallen to this amount, the water in the reservoir is drawn upon; and during May the volume of water passing down into the river below the dam is gradually raised from 500 to 750 cubic metres (from 17,650 to 26,500 cubic feet) per second. By the end of June the volume of water is raised to about 1,000 cubic metres (35,000 cubic feet) per second; and by about the 7th July the reservoir is empty, and all the sluices are open to receive the flood again. The opening of the sluices while the reservoir is being discharged will be in inverse order to the closing while the reservoir was filling; and the fifty sliding sluices at R.L. 92·00 (301·75) will not be opened until the discharge of the reservoir is completed.

The above outline of the operations during one season is, as stated, applicable only to an average year. In an exceptionally high flood, such as occurred in 1878–1879, the discharge of the Nile may rise to 14,000 cubic metres (494,500 cubic feet) per second, in which case the flood-waters would be discharged through the sluices under a head of about 3·5 metres (11·48 feet)

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and with a velocity of about 6·5 metres (21·32 feet) per second. In such a year the filling of the reservoir would begin much later than in an average year. Again, in a year of exceptionally low flood, such as 1899–1900, the filling of the reservoir would have to begin much earlier than in an average year.

Fig. 7, Plate 1, shows in full lines the discharge of the Nile and the readings of the Assuan gauge as an average of 20 years. The smaller hatched areas on the discharge-diagram show the amount of water taken from the Nile during the filling of the reservoir, and the amount returned to the river in the summer. In the gauge-diagram the dotted lines show the variation in the level of the river, due to the action of the reservoir. Fig. 8 shows the corresponding discharges and river-levels with the very low Nile of 1899–1900.

From these diagrams it will be seen at once that there could be a considerable variation in the date of beginning to fill the reservoir, which, within certain limits, would affect no other interests on the river. It is naturally desirable to draw from the river as soon as the water has become free from silt after the flood, so as not to reduce the flow of the river later on, when there is an important boat-traffic, both of tourists and of merchandise. In a year of exceptionally low flood the water is clear of silt much earlier than in an average year; so that filling the reservoir as early as possible has every advantage. The capacity of the reservoir is so small, however, in comparison with the amount of water available for storage, that there will never be the least difficulty in filling it. As already stated, the original design for the reservoir with the water-level at R.L. 114·00 (374·00) would have given 2,500 million cubic metres (88,300 million cubic feet) of water, or nearly two-and-a-half times the quantity in the present reservoir. Even this large amount does not represent the extent to which the Nile could be drawn on if necessary. Even in the worst year it would be quite possible to store 5,000 million cubic metres (175,500 million cubic feet), if reservoirs for that purpose were made.

The larger hatched areas in Fig. 7 show what effect would be produced on the discharge of the Nile by storing 7,250 million cubic metres (247,200 million cubic feet) in an average year, with the corresponding readings on the Assuan gauge. The amount of water available for irrigation is shown considerably less than what is stored, so as to make allowance for all loss. Fig. 8 shows only 6,000 million cubic metres (212,000 million cubic feet) stored in a year of very low Nile, like 1899–1900. It will be seen that in the

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average year the filling of such a reservoir would begin on the 1st November. At that time the water is not quite clear of silt, but the quantity present is small. The following figures show the amount of matter carried in suspension by the Nile at Assuan during an average flood:—

	Cubic Metres.	Cubic Feet.
In August	32,000,000	1,130,000,000
In September	14,000,000	495,000,000
In October	7,500,000	265,000,000
In November.	4,000,000	141,000,000

By commencing to close the sluices on the 1st November, the velocity of the water would be so inappreciably diminished, that only a very small portion, if any, of the 4 million cubic metres (141 million cubic feet) of silt would be deposited in the reservoir. Should such a low Nile occur as that of 1899–1900, which was lower than any recorded Nile, it would be necessary to begin filling the reservoir on the 1st October. The two objections to commencing to draw water from the Nile so early are, that it might interfere with some of the basin irrigation lower down the river, and that there would be a large deposit of silt in the reservoir. With reference to the first objection, it is enough to say that if there was a reservoir with a capacity of 6,000 to 7,000 cubic metres so much of the country would be under perennial irrigation that the reduced amount of basin land would not be interfered with in any way. As to the silt-deposit, it must be remembered that in a very low Nile, such as that of 1899–1900, the amount of silt brought down by the Nile is much less than in an average year, in which 11½ million cubic metres (406 million cubic feet) of silt come down during October and November: it will probably be well on the safe side if it is assumed that this amount is reduced to 8 million cubic metres (282 million cubic feet) in a very low year. The closing of some of the sluice-gates on the 1st October would make a small diminution in the velocity of the river; and if, to be on the safe side again, it is assumed that 25 per cent. of the total silt coming down during October and November is deposited, there would be a deposit of 2 million cubic metres (71 million cubic feet) of silt in a reservoir having a capacity of 6,000 million cubic metres (212,000 million cubic feet), or about ⅓ of 1 per cent. of the capacity of the reservoir: and this *might* happen once in 30 years.

The foregoing figures are intended to show, not that so vastly larger a quantity of water could have been safely stored at Assuan, if the temple of Philae had not been in the way; but that the

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Assuan reservoir could have been made of treble its present capacity, and that there would still have been sufficient water in the Nile to form another reservoir of the same capacity higher up the river, either at Wadi Halfa or at one of the other cataracts, if the required area of reservoir and a good foundation could be obtained.

In working out the different heads under which gates will have to be raised or lowered, it will be found that the sliding gates may have to be worked when there is a depth of 4 metres (13½ feet) of water on the sill of the sluice. This would give a water-pressure of about 19 tons on the gate, and as its weight is about 7 tons, it could be lowered by its own weight under this pressure. Of the roller-sluices, some of those at R.L. 92·00 and 87·50 (301·75 and 287·00) will be opened under a head of about 7 metres (23 feet) when the reservoir is discharging. The friction in these sluices is so small that they can easily be worked under this head.

Preliminary Work.

Work was commenced in the summer of 1898; and early in May of that year the Author, with Messrs. Aird's agent, Mr. John A. C. Blue, Assoc. M. Inst. C.E., arrived at Assuan to start operations, and to make all the preliminary arrangements necessary for the large staff and the great number of workmen who would have to be employed.

It would be hard to imagine a more desolate and uninviting spot than the site of the dam at that time; and the tourist who now visits Assuan during a few months in the winter would hardly recognize it in the middle of the Egyptian summer, and without a single European living in the place. With the exception of a few native villages, no sign of life was anywhere visible. The five main channels of the river flowing between the barren and baked black granite rocks, and then forming a torrential cataract as they fell over the granite crest into the lower reach of the river, gave the impression that the contract time of 5 years was none too long for such an undertaking. The granite hills bordering the river, rising to several hundred feet above water-level, were covered on one side of the river by the bright yellow sand of the Sahara desert, and on the other by the dark granitic sand of the Eastern desert, which extends from the Nile to the Red Sea.

All workmen, with the exception of a few boatmen, had to be imported; the natives from Lower and Middle Egypt, and the Europeans principally from England and Italy. Houses had to be

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built, and arrangements made for feeding the men, before they could be brought to the site of the work. This preliminary business was taken in hand as quickly as possible; and as fast as accommodation became available, the number of men was increased. The Government acquired all the necessary land, not only at the site of the dam, but for some miles to the south, where it was necessary to start quarries, and to lay lines to the dam from them, and from the terminus of the existing railway.

Within 6 months, a large European village, with about a dozen shops and a large restaurant, was built on the east bank. On the higher ground a hospital was constructed, with separate buildings for Europeans and natives, and with isolated wards for infectious cases. Adjoining the hospital were built houses for three doctors, and quarters for nurses. Every attention was paid to sanitary requirements at all points of the works, and a staff of about a hundred men was specially detailed for this work. Arrangements were made for filtering all drinking-water; and an ice-machine, capable of producing 1 ton of ice per day, was obtained, so as to have plenty of ice for the hospital and a small amount for ordinary use. Proof of the satisfactory nature of the arrangements as regards the sanitary requirements is found in the fact that, although at times the population around the dam, either directly employed on or connected with it, did not fall far short of 15,000 persons, there was never any serious epidemic, and there were only a few occasional cases of typhoid and small-pox. The principal cases dealt with in the hospital were due to accidents, particularly accidents to natives in connection with the use of explosives. During the first 2 years, while excavation was going on in deep trenches, there were many cases of sunstroke.

A single line of railway, of 4-foot 8½-inch gauge, runs from Alexandria through Cairo to Luxor, which is about 120 miles north of Assuan. A line of 3-foot 6-inch gauge had just been constructed from Luxor to Assuan when work was commenced; but for the first 6 months it was almost entirely in the hands of the military authorities, as the Sudan Expedition of 1898 was then going on, and practically no ordinary goods were taken over the railway. Beyond Luxor, therefore, it was necessary to bring by water a large amount of the supplies for the dam; and a large quantity of plant and materials had to be kept there, to be brought on when possible. All food had to be brought from Cairo or Alexandria; and as it might take anything between a week and a fortnight to deliver it on the dam after leaving Alexandria, large supplies had to be kept in stock. On several

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occasions during the first 6 months the stock of food became rather limited.

For the supply of water to the houses and to the boilers and masonry, a reservoir-tank was cut out of the rock on the east side of the river, at a sufficiently high level to give a good water-pressure all over the works; the tank was supplied by steam-pumps fixed in the flow of the river. Mains were laid over the works, with service-pipes to all houses, baths, etc., and with connections all along the dam. When masonry work was in full swing, this service had to be supplemented by a tank on the west bank, and by other temporary tanks on timber staging at two or three points along the works, supplied in the same way, and furnished with distributing mains.

About 22 miles of temporary roads and sidings of 4-foot 8½-inch gauge were laid, of which the greater portion had to be taken up and re-laid two or three times, on account of the Nile flood. About 3 miles of mixed broad and narrow gauge line were laid, in order that the rolling stock of the Egyptian Railways, running on the line of 3-foot 6-inch gauge from Luxor to Assuan, might be brought to the cement-sheds and other stores on the works.

Lime-kilns, Hoffmann brick-kilns, cement-sheds, magazines, etc., were built during 1898; and, in addition to the houses for staff and workmen, it was necessary to erect also a police-station, post- and telegraph-offices, public baths, a church for Italian workmen, and various other buildings.

While this preliminary work was going on, Messrs. Aird lost no time in sending out large quantities of plant; and the completion of the works within the contract time is largely due to the great effort made to have on the works at the earliest possible moment all plant which might be required.

The resources of the Egyptian Railway Administration were on several occasions strained to their utmost in getting the plant, cement, coal and other materials from Alexandria to Assuan; and although on one or two occasions the stock, both of cement and of coal, ran low, there was never actually any time lost on this account. All cement and coal came from England to Alexandria; 75,000 tons of the former and 28,000 tons of the latter were used during the construction of the dam. This amount of material, in addition to all other supplies for the dam, thrown at irregular intervals on a single line of railway which at normal times has about as much traffic as its rolling stock can deal with, entailed very considerable extra work and organization on the part of the railway authorities.

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Description of the Dam.

As seen from the elevation (Fig. 2, Plate 1) the dam naturally divides itself into two lengths: one of about 1,400 metres (4,600 feet), which is pierced by sluices; and the other of about 550 metres (1,800 feet), which is solid. The section of the pierced dam is shown in Figs. 9 and 11, Plate 2, being taken through one of the sluices with sill at R.L. 87·50 (287·00); a section of the solid dam is shown in Fig. 10.

With two exceptions, the sluices are divided into groups of ten; each sluice is 2 metres (6·56 feet) wide, with a bell-mouth entrance. Between the individual sluices in each group there is a length of 5 metres (16·4 feet) of masonry; and between each group of sluices the length of masonry is increased to 10 metres (32·8 feet), and there is also a buttress, which increases the width of the dam by 1·15 metre (3·77 feet) at these points.

The batter on the up-stream face is 1 in 18, and on the down-stream face 1 in 1½. With the exception of that portion of the foundation-masonry which is built hard to the rock at the sides, the facing consists of squared rock-faced granite in courses varying in depth between 12 inches and 24 inches. All the face-work was laid by cranes, and is built on the up-stream side in 2-to-1 Portland-cement mortar, and on the down-stream side, with the exception of the two lower courses, in 4-to-1 cement mortar. The hearting is of granite rubble in 4-to-1 cement mortar; but for 0·67 metre (2·2 feet) above the bottom, and for a similar distance where built hard to the rock at the sides, it is in 2-to-1 cement mortar. Practically all the stone for the hearting was of such a size as could be laid by hand, and was carried on men's backs from the wagons to the dam.

It was originally intended that the hearting should be built in lime and burnt clay, as an abundant supply of both was easily obtainable. About 10,000 cubic metres (13,000 cubic yards) were actually built with these materials; but the contractors found it impossible to burn the clay and bring it on to the works at such a rate as was required in order to complete the dam within the contract time. It was therefore determined to use 4-to-1 cement mortar. The results of some tests made with the burnt clay and lime mortar in various proportions are given in the Appendix; but it may be useful to make a few remarks here on the mortar. The limestone, which was a nearly pure calcium carbonate, was obtained on the river-bank about 44 miles below the site of the work, and was boated

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up to the railway below the cataract, and then taken about 8 miles by rail to the kilns, where it was broken and burnt with about 2½ cwt. of coal to the ton. The lime was then slaked and screened, before being ground in the mills with the burnt clay. The clay was obtained alongside the railway, about 6 miles from the works, and was there made into bricks and burned in clamps. For burning it required about 1½ cwt. of coal per ton of rough clay, or 1¾ cwt. per ton of ground clay. When burnt to a light red colour, it was either ground in a mill or broken by beating it with pieces of wood, and was then screened. The resulting crushed clay had to pass a sieve of 400 meshes per square inch, with a residue of not more than 8 per cent. The clay and lime, in the proportion of 3 of clay to 2 of lime, with about 10 per cent. of sand, were ground together in an ordinary mortar-mill until thoroughly mixed. The resulting mortar, when the grinding, screening and mixing were carefully done, was excellent, and much more water-tight than 4-to-1 cement mortar. The average tensile strength after 28 days was 160 lbs. per square inch. But the amount of plant required for producing and for distributing over the works, sufficient mortar to build between 40,000 cubic yards and 60,000 cubic yards of masonry in a month, would be enormous. The lime mortar, too, does not set as quickly as cement mortar: which greatly interferes with the progress of work, when large quantities of masonry are being laid, and when it is necessary to run cranes on top of the work. The Author is also of opinion that, where—as in Egypt—all coal has to be imported from England, there is no saving in cost by using lime mortar. With cement mortar, the cement is burned in England or in some other country where coal is comparatively cheap; and at Assuan there was no difficulty in obtaining excellent sand. With lime mortar, the coal for burning both lime and clay, and for driving crushing- and mortar-mills, had to be imported. Where, on the other hand, fuel can be obtained locally, or where a good hydraulic limestone is found, lime mortar will probably be cheaper than cement.

With regard to the stresses which occur in the portion of the dam pierced by sluices, it is evident that, owing to the varying level of the sluices, to the varying heights of the water up-stream and down-stream, and to the fact of different sluices being open at different levels of water in the reservoir, the unit stresses vary in different lengths of the dam. For the purpose of simplifying the construction and making the design uniform, certain assumptions were made. In dealing with the masonry down to the sill of the

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lowest sluices, it was assumed that the length of 5 metres (16·4 feet) of masonry between the sluices took all the pressure of water over the length of sluice and masonry. Thus a length of 5 metres (16·4 feet) of masonry took the pressure due to a length of 7 metres (23 feet) of water. This is an assumption on the safe side. Below the level of the lowest sluices the lengths of water and masonry were equal; and the weight of all the masonry above the sluices was considered effective. The level to which it was intended to raise the water in the reservoir was 106 metres (348 feet); but in the calculations it was assumed that the water might be raised to the roadway-level of 109 metres (358 feet). The weight of the masonry was taken at 2,300 kilograms per cubic metre (143·5 lbs. per cubic foot). The actual proportion of mortar used varied between 35 per cent. and 42 per cent.; and the actual weight of the masonry in 4-to-1 cement mortar, with 40 per cent. of mortar, is 2,396 kilograms per cubic metre (149·5 lbs. per cubic foot). The assumed weight of 2,300 kilograms per cubic metre is therefore fair, making allowance for the impossibility of being certain that every stone is solidly bedded. The granite was obtained from a large number of quarries opened up within a radius of 2 miles of the dam; and there was practically no difficulty in obtaining stones of any size. A large number of northern Italians were imported for getting out the ashlar required, and the rubble was generally got out by natives. The sand used was a sharp, heavy, granitic sand, which had been washed down from the adjacent granite hills. The maximum pressure on the masonry under these conditions was, with the reservoir full, 4·35 kilograms per square centimetre (4·0 tons per square foot) on the down-stream side; and with the reservoir empty, 6·32 kilograms per square centimetre (5·8 tons per square foot) on the up-stream side. The International Commission fixed the maximum pressure at 5 kilograms per square centimetre (4·5 tons per square foot) with a full reservoir. The majority of the sluices were lined with granite ashlar of an average thickness of 0·67 metre (2·2 feet). The granite sills were alternately through stones and half stones. The former were 2·50 metres (8·2 feet) long, and therefore extended 0·25 metre (10 inches) under the side walls; the latter had a joint near the centre of the sluice, and extended 0·65 metre (2·13 feet) under the side walls. All sills were 0·65 metre (2·13 feet) deep. The granite lintels were 2·70 metres (8·86 feet) long, giving a bearing of 0·35 metre (1·15 foot) on each side wall, and were also 0·65 metre (2·13 feet) deep. There was a cast-iron domed lintel over

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the bell-mouth entrance. All ashlar was set in 2-to-1 cement mortar. Thirty of the lowest sluices were lined with cast iron.

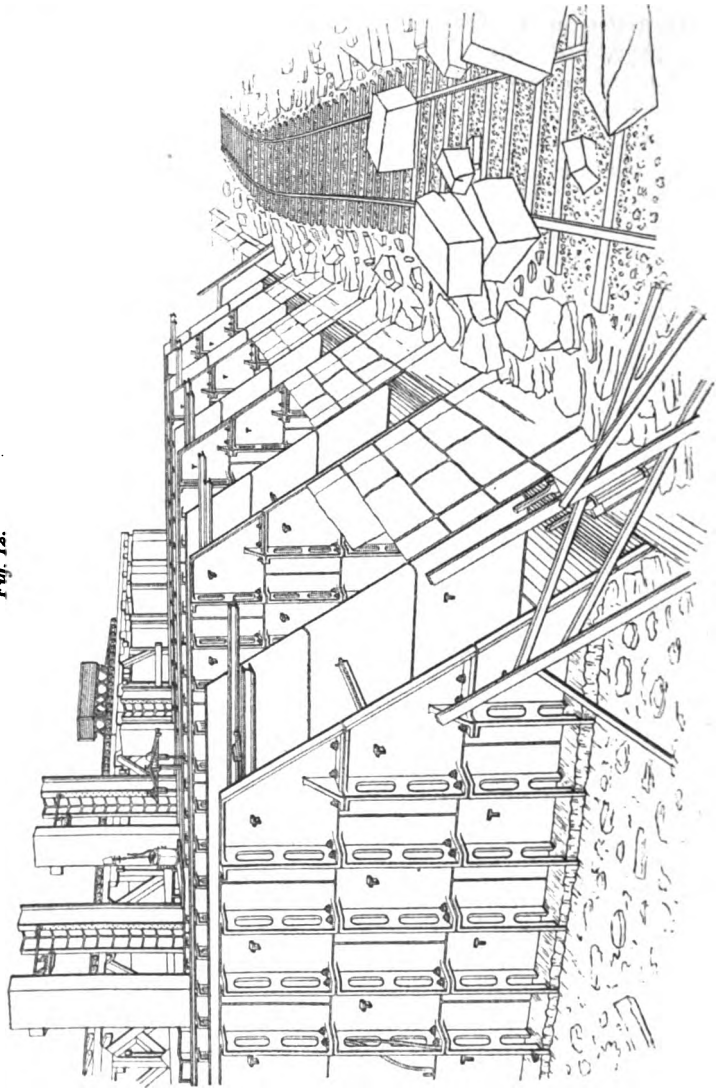

Fig. 12.

The rubble around the cast iron was built in 2-to-1 cement mortar for a thickness of 0·65 metre (2·13 feet); and the webs of the castings tied the lining well into the masonry. The only

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reason for the use of cast iron in preference to ashlar was that the iron could be laid much more quickly, and the time for working in some of the channels was very short. The cast-iron lining can be seen clearly in *Fig. 12.*

With the exception of the special plates at the ends of sluices and at the sluice-well, the plates were 5 feet 1⅛ inch long by 3 feet 9¾ inches high, and of 1½-inch metal. There were six rows of plates in the height of the sluice. Each plate had two stiffening webs at the back, 12 inches deep and 1½ inch thick. The plates in each row broke joint with those in the rows above and below, but were arranged so that the vertical webs came in line from top to bottom. The verticals were turned horizontally at top and bottom of each plate for 6 inches, so as to allow of two bolts connecting the rows of plates together at each stiffener. This was the only connection between the rows of plates. The cast-iron sills and lintels extended 12 inches beyond the inside line of the sluice on each side, were 2 feet 6½ inches wide, and were bolted to the stiffeners of the top and bottom rows of side plates respectively. Special plates were used at the bell-mouth entrance of the sluice; also at the down-stream end and on each side of the sluice-well. The weight of cast-iron lining in each sluice is about 110 tons. Felt pads were inserted between the vertical webs where bolted together; and these, in addition to small iron wedges, were used to adjust each row to the right level. The plates were not planed or machined in any way; the joints between them were pointed with cement on the inside of the sluice, as the masonry was carried up behind.

In case it should be necessary to repair one of the sluice-gates at any time, owing to its having become jammed, or for any other reason, a shield on the roller shop-blind system was devised, which could be lowered from the roadway of the dam so as to close the up-stream side of the sluice. This shield was designed by Sir Benjamin Baker, and the details were worked out and the shields supplied by Messrs. Ransomes and Rapier.

In going into the quantity of masonry which had to be built in a limited time, it was seen at an early stage of the work that the prompt delivery of materials at different points of the dam, as required, was one of the most important matters to be arranged. It was therefore decided to lay a three-track rail-road along the up-stream side of the dam, from the east to the west bank. For nearly half the length of the dam the road had to be carried on a heavy timber trestle (Fig. 14, Plate 2) 13 metres (43 feet) wide and having an average height of about 7·62 metres (25 feet). As

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each channel was pumped out, the trestle was built as quickly as possible, so that travelling cranes could command the excavation and masonry. The roadway of the trestle was at R.L. 94·50 (310·0), as this was the highest level to which it was considered safe to take the temporary dams, which also carried one or two lines of railroad. For about 3 months in each year, the trestle, being at this level, was of course covered for a depth of 4 to 5 metres (13 to 16 feet) by the Nile flood; and it had to be made sufficiently strong to stand the tremendous torrent of water rushing over it, for three seasons. A single road was generally carried along the down-stream side of the dam on either a temporary bank or a trestle; but it was useful only for material which could easily be carried on to the work, such as rubble or cement; for, owing to the greater batter on the down-stream side, cranes on this road could not command much of the masonry. During the month of June, 1900, 45,000 cubic metres (58,860 cubic yards) of masonry were laid, of which the larger portion was over a length of about 400 metres (1,300 feet) of the dam. The materials brought on to the trestle for the work required about sixty trains per day. As all materials had to be unloaded either by cranes or by hand on the trestle, careful and systematic arrangement was required in unloading and getting trains in and out in such limited space, in order to prevent any delay on the work. When the masonry was not above R.L. 98·00 (321·50), the facework on the up-stream side was generally laid by travelling cranes on the trestle; and that on the down-stream side either by cranes travelling on the masonry, or by derricks or travellers placed on prominent positions below the dam. As the masonry gradually rose above the trestle, all heavy stones were laid by cranes travelling on the dam.

The actual permanent work done during the first year, 1898, was small, in consequence of so large a quantity of plant and material having to be assembled on the site, and houses having to be built for the staff and workmen. The foundation-stone of the dam was laid on the 12th February, 1899, by H.R.H. the Duke of Connaught.

Temporary Dams (Fig. 14, Plate 2).

Some of the most interesting work in connection with the dam was the construction of the temporary dams—known in Egypt as "sudds"—enclosing the site of the masonry in the deep summer channels. This work was commenced at the east side of the river

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and continued westward. The five main channels from east to west are known as the Bab-el-Kebir, Bab-el-Haroum, Bab-el-Sogair, the Central channel, and the West channel. Sudds were constructed up-stream and down-stream of the site of the dam, and were made sufficiently water-tight to allow of the area between them being laid dry by pumping. It was necessary to make the sudds on one side of the dam of stone, in order to withstand the violent rush of water; as, owing to the dam being on the crest of the cataract, there is a fall in water-level of about 3 metres (10 feet) in a distance of 100 metres (330 feet) on each side of the axis of the dam. After the stone sudds had been constructed and the rush of water had been stopped, the sudds on the other side of the dam were constructed of sand in bags.

It was decided to make the stone sudds on the down-stream side of the dam, and during the summer of 1899 they were made in the Bab-el-Kebir, Bab-el-Haroum, and Bab-el-Sogair. This season was practically the first during which any work at the channels was begun; and as it was not possible to commence excavation before the flood, the only work done was the construction of the stone sudds. The object of constructing these sudds before high Nile was to obtain still water above them early in the following season, so that a sand-bag sudd could be commenced on the up-stream side of the dam as soon as the water fell to the level of the top of the stone sudd, which was 93·50 (307·00), or about 4·5 metres (15 feet) below the level of high Nile. The Bab-el-Kebir sudd was commenced on the 13th March, 1899. The larger stones, the weight of which ranged between 1 ton and 4 tons, were put in place singly by a crane working on the end of the sudd: the smaller stones were tipped from wagons and partly packed by hand. In some cases 2 to 4 tons of small stone were packed into wire nets and used instead of large stones; but the device was not altogether successful, as the wire nets were frequently cut against the stone, and all the small stones were swept down-stream. As the channel was closed, the current became so strong that large stones 2 or 3 tons in weight were frequently carried down-stream. The channel was successfully closed with the largest stones on the 17th May, under a head of 2 metres (6½ feet). The greatest height of this sudd was 15 metres (49 feet), the average width on top was about 9 metres (30 feet); the down-stream slope was 1 to 1, and the up-stream slope about ¾ to 1.

After the closing of the Bab-el-Kebir, the sudd was continued across the next channel, Bab-el-Haroum; this was much shallower, and no difficulty was experienced in closing it. Unfortunately,

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owing to the current not being so strong here, smaller stone was used than in the first channel; and this in all probability was the cause of a breach in the sudd which occurred when the Nile rose, and which is referred to later on.

The closing of the Bab-el-Sogair by a stone sudd was then taken in hand. This channel was 8½ metres (28 feet) deep over nearly the whole width, with one or two much deeper holes. The rush of water through it was very strong, and had of course been increased through the backing-up of the up-stream water by the construction of the two preceding sudds. Stones 3 to 4 tons in weight were carried away as the channel was narrowed, and at one time practically no progress was visible during a whole week. As the heaviest stones which a crane could lift were useless against the current, two large railway wagons were filled with wire nets of stone, each net of stone weighing 2 to 3 tons; the nets were then wired together and all secured to the wagons by steel ropes going over the nets and under the bodies of the wagons. Rails were laid to the extreme edge of the sudd, and the two wagons, each weighing about 25 tons, were run bodily into the cataract. These were able to withstand the force of the water, and formed a toe which prevented stone from being washed away. The sudd was finally closed on the 11th July, under a head of 3 metres (10 feet). By the closing of the three sudds the up-stream water was backed up a little over 1 metre (3·3 feet). The maximum head on the sudds after all were closed was 3·74 metres (12 feet). The down-stream side of all three sudds was pitched with stone by hand, and rails were built into the slope to keep the stone together; the crest of the sudd was rendered with cement.

The Nile gradually rose until, on the 16th July, it was level with the top of the sudds. On the 22nd July, when the water was flowing over them, the Bab-el-Haroum sudd was breached and nearly all of it was washed away. The head of water at the time of the breach was 3·45 metres (11·32 feet), which immediately after the breach, owing to the rising of the down-stream water, was reduced to 2·84 metres (9·32 feet). The cause of the breach was probably a slip on the down-stream side, which was accentuated by the small stone used in this sudd, and by the slow rise of the Nile. Both the other sudds withstood the flood with practically no damage. After the Nile flood, work on the sudds was recommenced on the 11th November, and on the 6th December, 1899, the stone sudd across the Bab-el-Haroum was again finally closed.

As soon as the Nile had fallen low enough, after the flood of

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1899, to cause comparatively still water above the stone sudds in these three channels, the sand-bag sudds were commenced. They were between 5 metres (16 feet) and 8 metres (26 feet) wide on top, with slopes of about 1½ to 1, and the greatest height was about 18 metres (60 feet). They were made with heavy granite sand in bags, about twelve bags to the cubic yard; and they were stanched by throwing quantities of sand and stone chippings on the up-stream side, which was eventually flattened to a slope of about 2 to 1. For the bottom of the sudd the sand-bags were at first brought to the site in a barge and thrown over the side; but the majority of the bags were brought by train on to the sudd, and carried on men's backs from the wagons to its advancing end. In closing the sand-bag sudds the same difficulty was not encountered as in the stone sudds, although some of them had to be closed under a head of more than 1 metre. Three methods, or a combination of the three, were used when closing the final gap. Sometimes a short stone sudd was formed up-stream of the line of the sand-bag sudds; and when the stone sudd was closed, it was stanched with sand-bags and sand. In other places, heavy timbers were put across the gap to be closed, in order to prevent the sand-bags from being washed away; and in some places a large number of sand-bags were put into a rope net, thus forming a sufficiently heavy mass to withstand the rush of water. The bottom of the river was here very irregular, and was covered with large boulders: consequently it was anticipated that the leakage through the sudds at the bottom would be considerable. It was found, however, when pumping was commenced, that the leakage was very small indeed. No doubt this was due to the great height of the sudd, and the consequent heavy weight pressing the lower layers of bags into the space between the rocks; and also to the continual running of heavy sand-trains on the top of the sudd, which must have helped considerably to consolidate it. The sudds were closed on the 15th January, 1900. After the sand-bag sudds had been closed, the water between the sand-bag and stone sudds fell to the level of the tail water of the cataract; and, where necessary, shallow subsidiary sand-bag sudds were built below the stone sudds, to keep out the down-stream water. The maximum head on the sand-bag sudds was about 10 metres (33 feet); and for the Bab-el-Kebir alone twenty-four 12-inch centrifugal pumps had been provided to deal with the anticipated leakage. Six pumps were first put in place, in order to lower the water and allow the other pumps to be fixed at a lower level; but after they had been started, it was found possible to pump the channel

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dry in 18 hours without additional pumps. After pumping out, two 12-inch centrifugals dealt with the leakage; and when the leaks were gradually stanched with sand, one 12-inch and one smaller pump were sufficient for all purposes. At the Bab-el-Haroum, one 4-inch pump dealt with the leakage; and at the Bab-el-Sogair two similar pumps were sufficient.

These three channels had been considered to be the maximum amount of channel-work which could probably be dealt with in that season (1899-1900), and at one time it had even been considered that to get in the foundation at the Bab-el-Kebir alone would be a good season's work. The extraordinarily low flood of 1899, followed by a rapidly-falling river, gave hopes that it might be possible to exceed even the larger programme; and it was decided to attempt to get in the foundations in the wide Central channel of the Nile, in addition to those in the three channels already dealt with. The stone and sand sudds were therefore continued across the Central channel, the water was completely shut off on the 20th February, and the whole discharge of the Nile was sent down the West channel, which was only 100 metres (328 feet) wide on the line of the dam. Pumping was commenced in the Central channel on the 28th February, with one 12-inch centrifugal pump. The water was quickly pumped out, and thereafter one 8-inch centrifugal dealt with the leakage. The total amount of stone used in closing the four channels was 64,000 cubic metres (83,700 cubic yards), and of sand 70,000 cubic metres (91,500 cubic yards). The number of bags used was 700,000.

Building Masonry.

During the season 1899–1900, work was therefore in progress in four out of the five main channels of the river; and by the first week in March, excavation was in full swing over this length of the dam, and masonry had been commenced in the Bab-el-Haroum. Over a considerable length of the excavation, however, the rock was found to be not solid, and in many places the rotten granite could be excavated with a pick. This was particularly the case in the Bab-el-Kebir and the Bab-el-Sogair. By the end of March the excavation in the Bab-el-Kebir had been carried down to R.L. 73·00 (239·50), or 9 metres (30 feet) lower than the level of solid rock shown on the contract-drawings; and at the Bab-el-Sogair the excavation had reached R.L. 79·00 (259·00), or 4 metres (13 feet) below contract level of rock. The same rotten granite

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continued to be met with during April, and by the end of that month solid rock had not been touched. Only 3 months now remained before all work for the season would have to be suspended on account of the Nile flood, and before that time the masonry had to be brought up to R.L. 94·00 (308·00); otherwise the sudds would have to be reconstructed in the following season. It was impossible to allow any doubt about the quality of the foundation, and excavation was carried on with, if possible, increased vigour. During the first week of May the bottom improved, and masonry was commenced on the 10th May in the Bab-el-Kebir, and on the 26th May in the Bab-el-Sogair. In the former the foundation-level was R.L. 70·5 (231·0), or 11·5 metres (38 feet) below the level of rock shown on the contract-drawings. The masonry in this channel had now to be built for a height of 24 metres (79 feet) in 2½ months, and as many masons as could possibly work together were put on here. In the meantime, at the Central channel bad rock was found in many places, and the final level of the foundation was about 2 metres (6½ feet) deeper than had been anticipated: it was not until early in May that masonry was commenced.

During the month of June, every effort was made to put in as much masonry as possible. Work was carried on every day of the week, and at the Bab-el-Kebir it was continued at night by means of electric light. The average number of masons employed daily during the month was 353, and 45,000 cubic metres (58,860 cubic yards) of masonry were laid during the 30 days. During July it was possible to stop night-work; and before the middle of the month, judging from the readings of the Nile gauges received by telegram from stations farther south on the river, it was seen that everything could be finished in time. On the 12th July the masonry in the Central channel was high enough to allow the sudd in that channel to be cut, thus relieving the head on the sudds in the other channels. This was followed by the cutting of the sudds in the Bab-el-Sogair on the 19th July and in the Bab-el-Kebir on the 22nd July. The Nile now had a free passage through the sluices; but, as it did not reach the level of the top of the masonry, it was possible to continue building from the timber trestle alongside the dam, until the first week of August. After that date the Nile quickly rose over the masonry, and all work was suspended.

An account has been given above, in some detail, of one season's operations, because otherwise it is difficult to realize the labour and anxiety in dealing with work of this kind, when it is absolutely

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necessary to finish a certain amount of masonry by a fixed date. On the one hand is the condition that there must be no risk as regards the foundation having reached good rock; and on the other hand is the fact that, unless the work is finished by the fixed date, the great cost of sudds and pumping will have to be incurred again in the following year. In the work under consideration, the difficulties were increased by having to carry the excavation to such a great depth below the level anticipated; in fact, the actual amount of excavation was about five times the amount provided for in the contract. The extra depth of excavation is not even a true value of the extra labour entailed, because there is the continual widening of the trench from the top when it is found that a further depth is required. It must also be remembered that all this rush of work had to be carried on under most trying climatic conditions. For 3 months the mean shade temperature during the day was about 108° F., frequently rising to 115° F., and sometimes to 120° F. The mean temperature at night was 85° F., and sometimes the thermometer did not drop below 100° F. at night. On some days during the month of June the thermometer in the sun registered 160° F., and on no day during that month was the maximum temperature in the sun below 140° F. It would, however, have been impossible to complete the amount of work actually done during the season 1899–1900, if the Nile had not been quite abnormally favourable. In an average year the Assuan gauge falls to R.L. 85·00 (279·0) and remains below R.L. 86·00 (282·0) from the 14th March to the 29th June; during the season in question it fell to R.L. 84·07 (275·75), and remained below R.L. 86·00 (282·0) from the 28th December to the 12th July.

The West channel was now the only one remaining to be completed during the season 1900–1901, and the sudds were commenced early in December, 1900. All the water coming down this channel enters through three narrow inlets some distance above the line of the dam. These inlets were closed by stone and sand sudds. Considerable difficulty was experienced in one inlet, but eventually, by using stones varying in weight between 6 tons and 12 tons, the channel was closed under a head of 3·75 metres (12·3 feet). By this means comparatively still water was obtained near the dam, and it was possible to construct the sudds both up- and down-stream of the foundation by means of sand, clay and soft stuff, very few bags being used. Both sudds were closed on the 4th February, 1901, and during the following week they were raised and considerably strengthened. Pumping was commenced on the 11th, with

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four 12-inch centrifugal pumps; but the leakage through the sudds was more than the pumps could master; so pumping was stopped in order to allow the leaks to be stanched with sand. It was again started on the 14th, with the same pumps, and continued until the 19th, when the water fell below the suction of the pumps. By this time, however, another 12-inch pump had been fixed at a lower level, and the bottom was practically dry on the 22nd. Thereafter, all leakage was dealt with by the 12-inch pump running about one-quarter time, and by one 8-inch pump and one 6-inch pump.

The same difficulties as in the other channels were experienced here by finding the upper rock quite rotten over the whole area. Although excavation was started in the middle of February, it was not until the beginning of May that the bottom was covered with masonry. The average depth to which it was found necessary to carry the excavation was 6½ metres (21 feet) below the level of solid rock shown on the contract-drawings.

While the work in the channels was going on, considerable progress was also being made all along the dam on the higher ground where sudds were not necessary; and by August, 1901, the foundation masonry was completed all along the dam, and all the masonry had been raised above R.L. 96·00 (315·0); so that no further temporary sudds were required, as the river rose above that level for only 3 months of the year.

In the higher ground also the decomposed granite caused trouble, the rotten rock extending in some places down to 8 metres (26 feet) below the contract level. Here a little expenditure on borings before the contract was let would probably have disclosed the quality of the rock; but it would have been impossible to find out to what depths the rotten rock extended in the channels, for, on account of the dam being built on the crest of the cataract, the quantity and velocity of the water rushing down them precluded all idea of boring, unless some temporary dams had been constructed, or a costly staging erected.

When it was considered that sufficiently good rock for foundations had been obtained in any length, the surface was washed and brushed, a careful examination was made, and if thought necessary a drill was put down for 2 or 3 metres (7 or 10 feet), in order to ascertain that there was nothing but solid rock below. As far as possible, all blasting was stopped a little above the foundation-level; and all loose or doubtful rock was quarried by bars and wedges down to that level. Although solid rock was reached, there were generally a few small springs visible when the surface was cleaned; and

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although the water came through what in most cases were practically hair cracks in the rock, yet its amount, owing to the head under which it came, rendered it necessary to deal with it very carefully. It had originally been intended to lead all springs through the masonry to the down-stream side of the dam; but in the end it was considered that, owing to the water coming in only through these fine vertical cracks, generally not more than 1 inch or 2 inches long, only a small local upward pressure could at the worst be exerted on the base of the dam, if the springs were carefully grouted with neat cement. The water from springs was always allowed to flow freely until the masonry around the springs had been built to a considerable height, and had set. For this purpose the water from a spring was either conveyed by a small pipe to a pump, or, if the spring was very small, was baled out by hand. If there happened to be two or three small springs near each other, they were connected by a pipe or a small channel built in the masonry. A chain or rope always ran through such a pipe or channel, from spring to spring, so as to make certain that the passage did not become blocked. After the masonry around each spring was set, the water was allowed to rise in the well so formed; and the masonry and the water in the well thus rose together, but the water was never allowed to rise on green masonry. In most cases, wells were connected by pipes at different levels, or the water was pumped from one to the other by a hand-pump; or where the levels of the ground and masonry allowed it, the water from one well was siphoned to another. Of course all the water was eventually brought to the main sump, where a steam-pump was fixed. As a general rule, all the wells were made large enough to allow of a boy going down to clean them out. When the masonry around a single well, or a series of wells, was of such a height that the water did not rise above it, the wells were cleaned out and grouted up solid with neat cement in still water. In a series of wells, the channels or pipes between them were well cleaned by pulling the ropes or chains through, and were all grouted up one by one: it could be seen that the channels were full, by the cement going from one well to another.

The foundation-masonry was laid in 2-to-1 cement mortar, and until the facework-level was reached, that which was built hard against the sides was in the same mortar. Where the foundation-level dropped suddenly, as in some of the deep channels, the masonry was gradually stepped down on the solid rock, on the longitudinal line of the dam; and a vertical key was also cut in

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the solid rock at each step, so as to prevent any tendency for a run of water along the line of the rock and the masonry. In some places, where the excavation was very rough and there was difficulty in building solidly to the rock, a space was left at the back of this key in the rock, and was afterwards cleaned out and grouted up with neat cement. Great care was taken that all masonry should be kept damp for several days after building, so as to be sure that the cement set thoroughly. The only way in which it was found possible to do this properly was to cover the masonry with heavy canvas immediately after building, and to soak the canvas with water several times during the day and night. The majority of the masons had to be trained to the work, as they had been accustomed to deal principally with soft stone and lime mortar; and the experience of a considerable number of those who applied for work as masons appeared to be confined to the purchase of a hammer and trowel. The worst were quickly weeded out, however, and under strict supervision by British inspectors a good class of solid masonry was obtained.

Locks and Navigation Channel (Figs. 15 and 16, Plate 2).

As the dam closed the river to navigation, it was necessary to construct a canal with locks, for ships to pass between the lower and the upper reaches. The canal, which had a bottom width of 12 metres (40 feet), was cut through the granite hill on the west side of the Nile (Figs. 2 and 3, Plate 1). It had to be carried a considerable distance below the dam, so as to avoid any rush of water from the sluices, and also in order to get clear of several small rapids. About 1,200 metres (1,300 yards) below the dam the west branch of the river widened, and was also of considerable depth; and this point was chosen for the canal-entrance. Between the entrance to the canal and the town of Assuan, there was another bad rapid in the river; and for several hundred yards in length at this place, one of the branches of the Nile was considerably widened and the bottom was brought to a uniform slope, with a view to diminish the strength of the current, and allow ships a free passage to the canal-entrance in all states of the Nile. In order to deal with the rapid, it was necessary to dam this branch of the Nile and pump out the water; because, owing to the rush of water, it was impossible to carry out the blasting-operations satisfactorily, except in the dry. The total amount of rock here blasted was nearly 20,000 cubic metres (26,000 cubic

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yards). Considerable difficulties were met with in the construction of the sudds, which had to be made at the top of the rapid in deep water, on account of a sudden drop there in the level of the bottom. Even after the large amount of work done there is still a rapid current; and it will be necessary to build a lock, which will be the most satisfactory although the most expensive way of dealing with the difficulty.

On the up-stream side of the dam the canal was carried some 800 metres (880 yards), so that ships might leave the canal at a point where there was no current of water towards the sluices. As the water-level up-stream of the dam when the reservoir is full has been raised to R.L. 106·00 (348·00), it was necessary to build a heavy pitched bank between the reservoir and the canal, because the ground-level on the line of the canal was not as high as the water-level in the reservoir. The total length of the canal was about 2,000 metres (2,180 yards), with a maximum depth of rock excavation of 16 metres (52 feet). As the excavation was in hard rock, the slopes were made about ¼ to 1.

Locks were provided for passing ships up and down the canal. During certain times when the reservoir is full, there may be a difference of 20 metres (66 feet) between the water-levels up- and down-stream; and a string of four locks situated just down-stream of the dam provides for passing the traffic. The total drop from the bottom of the upper canal to the bottom of the lower canal is 7 metres (23 feet), which is made up by 1 metre (3·28 feet) between the sills of the first and second locks, and 3 metres (9·84 feet) between the second and third and between the third and fourth locks. The difference between the surface-level of the two reaches may, however, as above stated, be as much as 20 metres (66 feet) when the reservoir is full; but when the reservoir is emptied, or just before the filling begins, the difference between up- and down-stream water-levels may amount to only 1½ metre (5 feet). The locks therefore have to be worked under a head ranging between 20 metres and 1½ metre (66 feet and 5 feet).

Each lock is 80 metres (263 feet) long and 9½ metres (31 feet) wide at the bottom, which is large enough for the anticipated traffic. The facing masonry of the locks is of much smaller size than the facing of the dam, and was all laid by hand. The sills, gate-floors, quoins, etc., are, however, of heavy granite ashlar. Each lock-gate consists of a single leaf, and rolls back into a recess in the masonry. Owing to the small depth of water at certain times, it would be useless to make these gates of the caisson type, and they are therefore suspended on rollers from

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a bascule bridge crossing the lock, so as to leave the waterway free when the gate is drawn into the recess. The two upper gates (Figs. 16, Plate 2) are 18 metres (59 feet) deep, and weigh about 105 tons each, exclusive of the bascule, etc. The three other gates are 14 metres, 11 metres, and 8 metres (46 feet, 36 feet, and 26 feet) deep. The opening and closing of the gates, as well as of the valves in them, is done by hydraulic power supplied by pumps which are driven by a turbine fixed in the dam. There is no culvert in the masonry for adjusting the water in the locks, but a large number of sluices are provided in the gates.

A brick culvert is built at a low level behind the lock-walls on each side, so that, should there be any leakage from the reservoir when full, through fissures in the rock to behind the walls, the water may be carried down-stream, and not allowed to rise. The culverts are seen in the section through the deepest lock, shown in Fig. 15, Plate 2.

Before the construction of the dam and canal, steamers could pass the cataract at high Nile only, and even then under considerable difficulty. For some months after high Nile, it was possible to haul sailing-boats through by means of a couple of hundred natives hauling on ropes; and it sometimes took 2 days to get a comparatively small boat through. All kinds of boats will now be able to pass without difficulty at any time of the year.

Temple of Philae.

In the first proposal for a reservoir at Assuan the level of the water would have been raised to such a height as would have inundated the temple of Philae, which is picturesquely situated on an island in the middle of the Nile, about 1 mile above the dam. Under the scheme now completed, although the water-level will rise only to the floor of the temple, it was found necessary to take precautions to prevent any settlement of the temple buildings when the reservoir was filled. Fortunately, a large portion of the main temple has been founded on rock; but the rock-level falls quickly towards the south, and the beautiful colonnade at the south end of the island was built almost entirely on silt.[1]

At one side of the colonnade it was found that cross walls or counterforts of a quay-wall had been carried down to rock; and the long row of pillars forming that side of the colonnade was carried on sandstone sills extending from counterfort to counterfort. The sills, however, were cracked and broken, and many were

[1] See *Engineering*, vol. lxxv. p. 121.

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supported only by the silt between the walls. The ground between the walls was therefore excavated, while the sandstone sills supporting the columns were temporarily propped; and steel girders were fixed below ground-level from counterfort to counterfort, and the weight of the colonnade was taken by them. The steel girders were then completely surrounded with cement masonry, made thoroughly water-tight by forcing in cement grout.

The other side of the colonnade was underpinned in short lengths in cement masonry, down to the old saturation-level of the ground. The well-known Kiosk, or Pharaoh's Bed, was dealt with in a similar way. In many places the underpinning was carried down for a depth of 25 to 35 feet from ground-level. Many of the other temple buildings were also made secure.

In nearly all places where the underpinning was done, the superstructure of sandstone, in some places 60 feet or 70 feet in height, was in a very dilapidated condition. The columns were out of the vertical, and the sandstone lintels, weighing many tons, were often cracked right through. It is difficult to realize the constant care and attention which such work required; and the safeguarding of these temples, instead of being referred to in a few lines in this Paper, would certainly be worthy of a Paper to itself.

Conclusion.

All the foundation-work of the dam was completed in the summer of 1901, and all the masonry was finished in June 1902, which was 1 year before the contract time, and less than 3½ years after the first stone was laid. The contract quantity of excavation in the dam and locks was 312,000 cubic metres (408,000 cubic yards), and the actual quantity excavated was 630,000 cubic metres (824,000 cubic yards). The total contract quantity of masonry was 370,000 cubic metres (484,000 cubic yards), and the actual amount built was 538,000 cubic metres (704,000 cubic yards). The quantity of excavation was therefore double that anticipated, and the quantity of masonry was 45 per cent. greater than expected; yet, with all this extra work, Messrs. Aird, the contractors, managed to get all finished 1 year ahead of their contract time. Messrs. Ransomes and Rapier had also to get all their ironwork completed 1 year before their contract time, and this they successfully did.

It may be of interest to state that the actual cash cost of the works came to nearly £2,450,000; which works out at about £62·5

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per million cubic feet of water impounded, or practically £10 per million gallons.

During the winter months Assuan is visited by a large number of tourists, principally English and American, and enjoys a high reputation as a winter health-resort. During those months the climate is nearly perfect; and, owing to the almost complete absence of rain, and the dry and clear atmosphere, it is without doubt a very suitable place for many invalids. This spell of comparatively cool weather, however, is of short duration, and the hot weather generally commences suddenly at the end of March. From that time until the middle of November, the climate is very trying to Europeans; and during the months of May, June, July and August, the extreme heat is nearly unbearable. It was during the first three of these months that the construction of the dam necessitated the largest amount of work; and during one summer, cases of sunstroke, some fatal and many serious, were of daily occurrence. The natives appeared to suffer almost as much as the Europeans. During June all work had to be suspended between 12 o'clock and 4 o'clock in the middle of the day. Owing to the narrowness of the Nile valley at Assuan, and to the high granite cliffs on both sides of the river, the radiation at night from the rocks which have been heated during the day is enormous; and for 6 months a cool night is never experienced. Hospital-tents, with a plentiful supply of cooled water, both for drinking and for immersing sunstroke patients, were placed at short distances apart throughout the works; and iced baths were always ready in the hospital built on the works. For a long time three doctors were employed; but after the rush of work was over, the number was reduced to two.

As already stated, Sir Benjamin Baker was the Consulting Engineer to the Egyptian Government, and he with Sir John Aird, Bart., visited the works every winter. The successive Directors-General of Reservoirs were Mr. W. J. Wilson and Mr. A. L. Webb, MM. Inst. C.E. From the beginning of the work in 1898 until December, 1901, the Author had charge of it on behalf of the Egyptian Government; and was succeeded by Mr. C. R. May, M. Inst. C.E., who had previously been principal assistant. The staff employed was necessarily large; and among its many members the Author would mention Messrs. M. Macdonald, W. L. Brown, A. T. Binnie, H. F. Carew-Gibson, W. T. W. Somers, A. C. Rettie, Assoc. MM. Inst. C.E., W. Roberts, C. Mackenzie, and R. Milne, as having given him great assistance; as also Dr. J. Ball, Assoc. M. Inst. C.E., and Mr. Mat Talbot, under whose

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supervision the work at the temple of Philae was carefully carried out.

Messrs. Aird's Agent was Mr. John A. C. Blue, Assoc. M. Inst. C.E.; and he was ably assisted by Messrs. W. N. Bakewell, M. Inst. C.E., J. McClure, McCorquodale, Landry, McPherson, E. Allesandrini, Urquhart, Hope, and many others.

Messrs. Ransomes and Rapier, of which firm Mr. Wilfrid Stokes, M. Inst. C.E., is Managing Director, were represented on the works by Mr. E. H. Tabor, Assoc. M. Inst. C.E., who was assisted by Mr. G. S. Perry, Assoc. M. Inst. C.E.

Dr. E. Schmitt organized the medical and sanitary arrangements in connection with the undertaking; and among others Drs. White and Fahry carried out this work, and made many further improvements after Dr. Schmitt retired on account of ill-health.

To the Under Secretary of State for the Public Works Department, Sir William Garstin, G.C.M.G., under whose control the work was carried out, the Author owes his gratitude for much valuable advice and ever-ready help in all difficulties. It is almost needless to say that Lord Cromer gave all possible assistance in carrying out the work.

His Highness the Khedive and the Egyptian Ministers, particularly H. E. Sir Hussein Fakhry Pasha, K.C.M.G., Minister of Public Works, who frequently visited the works while in progress, gave their full support to an enterprise which is destined to increase the wealth of the country, and to lessen the great anxiety with which the rise of the Nile has been regarded in past years, since on this it depended whether the year was to be one of plenty or one of famine.

The Paper is accompanied by eleven tracings and five photographs, from which Plates 1 and 2 and the Figures in the text have been prepared.

[APPENDIX.

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APPENDIX.

Result of Long-Time Tests of Lime and Clay Mortar.

Tensile Tests.

Clay was medium burnt; lime was newly burnt; sand was screened granite sand.

Mixture.	Age. Weeks.	Ultimate Tensile Strength: Lbs. per Square Inch.	
		Individual Tests.	Average.
3 parts by volume clay	13	334,330,354,382	350
2 ,, ,, ,, lime	26	324,314,332,314	321
	52	356,356,292,346	337
2 ,, ,, ,, clay	13	330.316,298,304	312
2 ,, ,, ,, lime	26	358,324,294,354	332
	52	366,400,390	385
3 ,, ,, ,, clay	13	248,248,246,238	245
2 ,, ,, ,, lime	26	292,258,262,280	273
1 ,, ,, ,, sand	52	314,300,300,302	304
2 ,, ,, ,, clay	13	304,310,302,316	308
2 ,, ,, ,, lime	26	324,322,330,350	331
1 ,, ,, ,, sand	52	352,322,312	330
1 ,, ,, ,, clay	13	260,268,236,220	246
2 ,, ,, ,, lime	26	262,284,274,264	271
2 ,, ,, ,, sand	52	310,298,296,288	298
1 ,, ,, ,, clay	13	216,170,250,238	220
2 ,, ,, ,, lime	26	290,296,242	276
1 ,, ,, ,, sand	52	338,304,278,270	297
1 ,, ,, ,, clay	13	240,198,242,216	224
1 ,, ,, ,, lime	26	270,222,254,230	244
1 ,, ,, ,, sand	52	268,302,260,256	271

Compression Tests.

Mixture.	Age in Months.	Averages, Tons per Square Foot.
1. Medium-burnt clay (3 clay to 2 lime); three 6-inch cubes	7	105·7
2. Underburnt-clay (3 clay to 2 lime); two 2-inch cubes .	8	154·8
3. Medium burnt clay (3 clay to 2 lime); two 2-inch cubes.	8	126·3
4. Overburnt clay (3 clay to 2 lime); two 2-inch cubes . .	8	137·1
5. General mixed sample of clay (3 clay to 2 lime); two 2-inch cubes	8	151·0

Notes.—1. All lime and clay passed through a sieve of 529 (23 × 23) meshes to the square inch.

2. Sand passed through sieve of 400 meshes, and retained on one of 900 meshes, to the square inch.

3. Cubes kept for the first 7 days under a damp cloth, and then for 6 months in water.

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(Paper No. 3393.)

"Sluices and Lock-Gates of the Nile Reservoir, Assuan."

By FREDERICK WILFRID SCOTT STOKES, M. Inst. C.E.

ALTHOUGH this Paper relates to the sluices and lock-gates of the Nile Reservoir, it is necessary in the first place to consider shortly some matters in connection with the dam itself and other general conditions. The dam is about 1¼ mile long, and is built of granite masonry set in Portland cement. It extends in a straight line from the east bank of the Nile to the west bank, about 4 miles south of Assuan, at a spot where the river widens out abnormally.

As is generally known, the Nile rises each year about the end of June, and when in flood brings down a considerable amount of matter in suspension, which is of great value as a fertilizing medium. It is therefore doubly important that a dam should not, by checking the flow of the river, cause this matter to settle in the reservoir. Consequently culverts of sufficient area had to be provided for allowing the flood to pass through the dam under only a small head. As the period of flood comes to an end, the water becomes comparatively clear in November; and the openings in the dam may then be gradually closed, so as to fill the reservoir while there is water in excess of the requirements lower down the river. When (about the end of April), the reservoir being full, water becomes scarce, the culvert-sluices must be gradually opened again so as to supplement the normal flow of the river. The height of dam ultimately decided upon raises the water-level about 66 feet 6 inches, and the maximum head above the sill of the lowest culverts is 61 feet.

The design of culvert adopted is rectangular in section, 2 metres (6 feet 6¾ inches) wide by 7 metres (23 feet) high; and hence sluices to close the culverts have to withstand a pressure of nearly 210 tons each, with the maximum head.

After careful examination of the best continental and English

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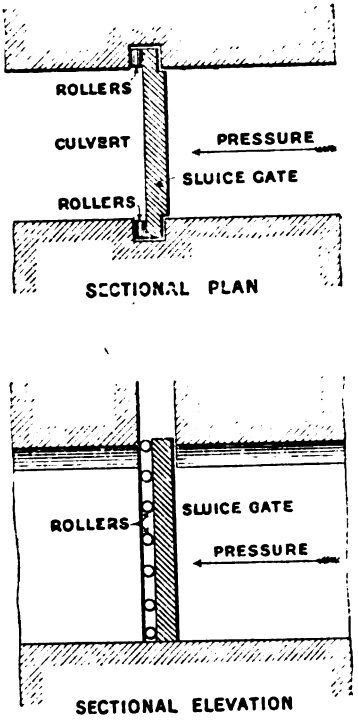
sluices, it was found that the most suitable system, in fact the only one practicable, was that invented by the late Mr. F. G. M. Stoney, M. Inst. C.E. In the Stoney sluices two frames, containing a number of free or live rollers, are interposed between the fixed framework and the moving face of the sluice (*Fig. 1*), so that, instead of a sliding friction, which under the above conditions would probably amount to over 100 tons, a rolling friction only has to be overcome, which would not exceed ½ ton; in fact, the rolling friction in such a case forms only a small part of the work to be done when raising an unbalanced sluice.

Fig. 1.



The designing, construction, and erection of the work were entrusted by the Egyptian Government to Messrs. Ransomes and Rapier, of Ipswich, under the supervision of Sir Benjamin Baker, K.C.B., K.C.M.G., Past-President Inst. C.E.

There are one hundred and eighty sluices in the dam, placed in groups of ten, 7 metres apart from centre to centre, and each 2 metres in clear width, thus giving a clear waterway of 360 metres (1,281 feet), or about the width of the Thames at Westminster Bridge. Sixty-five of the sluices are placed at R.L. 87·5,[1] seventy-five at R.L. 92, eighteen at R.L. 96, and twenty-two at R.L. 100, the maximum level of water in the reservoir being R.L. 106. They are designed, however, to hold up water to the top of the dam, R.L. 109, should it be found advisable later on to increase the capacity of the reservoir.

Owing to the circumstances under which the regulation of the flow will take place, it was not necessary to have all the sluices fitted with free rollers. Consequently fifty sluices at R.L. 92

[1] Height in metres above mean sea-level.

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are simple sliding doors, which are to be lifted and lowered at times when there is a head of not more than about 3·5 metres (11 feet 6 inches) against them. The weight of the sluice, about 9 tons, will then be sufficient to ensure its closing without trouble.

The culverts of the sluices at R.L. 96 and R.L. 100 are only 3·5 metres (11 feet 6 inches) high. These forty sluices will be used for regulating the discharge when the reservoir is nearly full: after which the twenty-five sluices with rollers at R.L. 92, and finally the sixty-five at R.L. 87·5, will be opened, when the reservoir is nearly empty. Any of these sluices, however, can be worked, whatever the level of the water may be; the crabs for working are geared so as to enable one man to raise a sluice under a full head.

As the conditions to be complied with vary considerably, the design of the sluices at the several levels differs. There were, of course, several points to be borne in mind when designing the parts, such as reduction in time and cost of erection with comparatively unskilled labour, under conditions when speed was of the first importance. The weight of each piece for shipment and subsequent handling had also to be carefully arranged, so as to be in keeping with the foregoing requirements without adding to cost of transport. Most of the pieces shipped were under 2 tons in weight, and among the remainder there were but few weighing more than 3 tons.

The parts to be built into the dam were required much in advance of the sluices themselves, and were sent off before the sluices were made; it was therefore necessary to work strictly to gauges, and to make all parts interchangeable. All the parts of each set were put together at the works at Ipswich, and were carefully gauged before shipment, with the result that the erection was carried out without the slightest hitch or delay. It was also possible to employ native labour to a large extent, because the Egyptians quickly learned how the parts came together; and, owing to the repetition of so many similar sluices, they required, after a time, comparatively little supervision.

Sluices at R.L. 100 and R.L. 96.

These forty sluices are more particularly for regulating the discharge when the reservoir is full, and, as their level indicates, have only 6 metres (19 feet 8 inches) and 10 metres (32 feet 10 inches) of head respectively over the sill (Fig. 2, Plate 3). The culverts are 2 metres (6 feet 6¾ inches) wide by 3·5 metres

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(11 feet 6 inches) high. The entrance to the culvert is bell-mouthed and is roofed over by a casting curved on the dam-face and flat at the place where it joins the sluice-lintel. The grooves, lintel, and sill of the sluice are all of cast iron, arranged with machined faces and put together with turned bolts. The sluice is built up of a steel-plate skin with rolled strengthening girders at the back, framed into cast-iron beams on each side, which form the roller-paths. Adjustable bars are fitted on each side of the face, to reduce the leakage as wear takes place, owing to the cutting action of the silt in the water. On the top of the sluice is also fitted an adjustable bar, which shuts down on the lintel at the same moment that the bottom of the skin lands on the sill, and thus makes a water-tight joint. The rollers are arranged in cradles formed of flat bars, and are hung in position on each side of the gates by steel-wire ropes.

The crab (Figs. 8, Plate 4) has two speeds of lift, namely, for small adjustments by one man, or for quick working by four. An automatic self-sustaining gear is provided, so that the sluice (which is not counterbalanced in any way) cannot run down, the handles having to be turned when lowering, in order to release the gear. The barrel-shaft is worked by means of a worm-wheel, and a worm fitted with a ball thrust-bearing. All the bearings and pulleys are fitted with screw-down grease-lubricators; this is the more advisable owing to the sand and dust.

As all the crabs had to be made before it was possible to ascertain the resistance of the sluice in working, and as the suspending ropes for the sluices of the lower levels were arranged with a considerable number of parts (*e.g.*, ten for those at R.L. 87·50), it was advisable to ascertain, as far as possible, the loss due to the bending of the ropes under full load. It was found that about one-sixth of the total work done was absorbed by the pulleys and ropes. The flexibility of different makes of rope, which to all appearances were similar, was found to vary considerably. Where steel-wire ropes are used for frequent lifting, economy in first cost is therefore not true economy in working, because the cheaper forms of rope are far less flexible when loaded. A rope which when free may easily be bent in the hand becomes comparatively rigid when its wires are tightened and locked together under a load. The reasons why so many parts of rope and such a comparatively wasteful reduction as worm-gearing were employed were the convenience which such an arrangement afforded, the cheapness of labour at Assuan, and the fact that the regulation of sluices is practically of only annual occurrence.

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SLUICES AT R.L. 92. (Figs. 3, Plate 3.)

Sluices Without Rollers.—These fifty sluices are 7 metres (23 feet) high by 2 metres (6 feet 6¾ inches) wide. Being simply for the purpose of closing the culverts, they are not to be worked against a head of more than 11 feet 6 inches; they have, however, to withstand a head of 14 metres (45 feet 11 inches) over the sill. The grooves, sill, lintel, and front roof are of cast iron; and the gate is formed of wrought-steel joists and plates, faced with planed bars bearing against the machined face of the fixed framework. The sluice is lifted by a six-part steel-wire rope, winding two parts; the lower pulleys are arranged between plate cheeks attached to the sluices by two pins, which, when withdrawn, allow the rope-gear to be wound up clear of the water during the time the reservoir is full. When it is empty, and the period of high Nile is approaching, the lifting-gear is again lowered and attached, and the sluices are raised as the flood begins. The crab and platform are similar to those for R.L. 100 and R.L. 96.

Sluices With Rollers.—These twenty-five sluices are 7 metres (23 feet) high by 2 metres (6 feet 6¾ inches) wide, and are for the purpose of regulation when the fifty without rollers have been lowered, and before the water rises high enough for those at R.L. 96 and R.L. 100 to give the required discharge.

As the head above sill-level is 14 metres (45 feet 11 inches), the rollers and other parts have to be of much more ample proportions, and the grooves built into the masonry of considerably larger size, than those for the sluices at R.L. 100 and R.L. 96. The action of the water passing through the culvert at a high velocity has also to be avoided; hence the rollers are kept well back from the face, and an inclined shield-plate is provided to protect them from the direct flow. A whirlpool motion is set up in the grooves, but it is not of sufficient force to disturb the rollers hanging below the bottom of the gate when raised. The grooves are built of four sections, weighing about 2 tons each. They are bolted together with turned bolts, and are arranged with projections on each side, to key into the masonry and prevent the leakage of water round the back. The sluice is built of heavy specially-rolled steel joists, with steel skin-plates and cast-iron roller-path girders on each side.

A vertical rod, which is contained in a groove bolted to the skin on each side of the face, is pressed by the water into the corner formed by the face of the sluice and the face of the fixed frame, and thus makes a watertight joint; a horizontal rod fitted

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in the lintel also serves the same purpose. This provision is not necessary for preventing leakage, but is intended to guard against the cutting away of the faces by the fine matter carried by the water. It may be mentioned here that Nile water has a peculiar action on paint or other protective coating; and it is quite usual to have to repaint all metal-work that has been under water during each flood, because all traces of paint have as a rule been removed by the attrition of the fine silt in the water at high Nile. All kinds of special paints and varnishes have been tried, but with little success. It is curious that the best standing paint on the sluice-work has been the common white-lead letters put on at Ipswich for marking the various parts to facilitate erection.

The sluice is hung on a ten-part steel-wire rope winding two parts. The crab and pit-covers are similar in design to those for R.L. 87·50.

Sluices at R.L. 87·50.

It was originally intended to have the lowest sluices in the dam at R.L. 84, but it was found that R.L. 87·50 would suit the surface-levels and channels better. The head of water above sill-level is 18·5 metres (60 feet 8 inches), giving a pressure of about 210 tons against the sluice. The entrance to the culvert is bell-mouthed, and roofed by an arched casting (Figs. 4, Plate 3). A slight drop is arranged on the down-stream side of the sluice-sill, which has been found to reduce greatly the wear and tear on the culvert-bottom, and to give a freer discharge under the sluice. A similar drop has been given to the other culverts. The grooves are built of four sections, bolted together and to the lintel and sill castings. Stanching-rods are fitted to the sluice, as in those for R.L. 92 with rollers. The gate is built of special rolled steel joists framed into two cast roller-paths. The skin is riveted to the joists in sections, which when in position are finally fixed together by turned bolts. The sluice is carried by a steel-wire rope in ten parts, arranged round pulleys on the gate and on girders at the pit-top. Forced grease-lubrication is employed, as in the other sluices and gear. The crab is similar in design to those for the sluices at R.L. 96 and 100.

Culvert-Linings.

As the deep channels had to be "sudded" off in order to get the foundations of the dam built in one season, it was decided to line the culverts for thirty sluices with cast iron, which rendered the

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masonry operations much easier and more expeditious. The linings (Figs. 4, Plate 3) are courses of plates ($1\frac{1}{2}$ inch thick by 5 feet $1\frac{1}{8}$ inch by 3 feet $9\frac{3}{4}$ inches), bolted together by vertical bolts, and set so as to break joint. It was thought that, owing to the wide range of temperature during the time the plates were exposed to the sun, the expansion and contraction might cause them to shift before the masonry had set; and felt pads were therefore placed between the faces bolted together. As the plates were only rough cast, this also gave a means of adjustment while erecting. Two stiffening ribs were cast on the back of each plate, with oblong holes in them so as to key into the masonry when the plates were grouted in. The plates were coated in England with Dr. Angus Smith's composition, which stood well the action of the Nile water.

Special plates with sloping ends are provided for the up- and down-stream faces of the culverts. The top and bottom plates are half the width of the side plates; they have one rib at the back only, and the bottom plates are made with several holes for grouting when fixed.

In order to keep the plates in position while the masonry was built up against them, each plate was cast with a T-shaped hole in it to receive a T strut fitted at each end with wedge-shaped keys. These struts also formed a support for the platform from which to erect the next course of plates. During the second season's work twenty sets of lining were erected; and notwithstanding the fact that the work had to be carried out so as not to check the masons, the whole twenty sets, comprising 3,200 plates, weighing in all over 2,200 tons, were got into place in less than 8 weeks. The twenty sets of grooves for the sluices had also to be erected during this time, making a further 640 tons.

Lock-Gates (Figs. 5, 6, and 7, Plate 3).

As vessels have to pass through the locks at all heights of the water-level in the reservoir, the sill of the upper lock has to be at R.L. 90, *i.e.*, 19 metres (62 feet 4 inches) below the roadway of the dam and quay-level. This necessitated a special design of gate, and for the sake of uniformity all the gates were made alike. There are four locks, each 9·5 metres (31 feet 2 inches) wide and 80 metres (262 feet 6 inches) long. Commencing at the upper end, the heights of the successive gates are 18 metres (59 feet), 18 metres, 14 metres (45 feet 11 inches), 11 metres

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(36 feet 1 inch), and 8 metres (26 feet 3 inches). The sills are at such a level as to give a drop of about 6 metres between each lock. The great range of water-level prevented the gates from being floated in any way; and they are therefore hung from above, upon two sets of free rollers which are supported upon two bascule girders spanning the lock (Fig. 6). The girders enable the gate to be moved back into a recess in the side of the lock, after which they are raised so as to allow free passage for vessels.

The 18-metre gate with its carriage weighs 105 tons, and requires a force of about 1 ton to travel it. The gate is formed of fourteen horizontal bowstring girders, spaced so as to be practically equally loaded, bearing against two built-up jamb members faced with greenheart. Cast-iron facings are bolted to the masonry for the jambs to bear against when the gate is closed. The skin is formed of steel plates stiffened by vertical bulb tees. Twelve sluice-openings, arranged in four groups, are formed in the skin for filling the locks; the water from one lock passes to the next through these sluices, there being no culvert-sluices.

Although the locks are all of the same length, namely, 80 metres (262 feet 6 inches), the plan of passing water from one lock to the next is open to the objection that, if successive boats are passed without correcting the water-level, the upper locks become unduly empty. It is thus necessary to equalize the drop between each lock after each operation, so as to be ready for passing a boat in either direction.

The gates are strong enough to withstand the full head that can come upon them with the down-stream side dry. In the largest gates this pressure amounts to 1,568 tons; but under normal working the pressure is only 1,407 tons.

The gate is hung by fourteen sling-rods, placed in pairs, so as to accommodate the altered position of the centre of gravity as the water-level varies, and thus maintain the gate in its true vertical position. The sling-rods are so placed on the carriage as to keep the gate clear of its seatings, until acted on by reducing the water-level slightly. The carriage is built up of two roller-path members, and seven cross girders carrying the sling-rods. The rollers are in frames, hinged at a point near the bascule-girder pivot, so as to allow the bascule to rise. A timber platform covers the carriage, and gives access to the gear. The bascule girders are of fish-belly box section, arranged with the tail end of each between two fixed girders carrying the roller-path. Cast-iron counterweights are provided to balance the bascule girders, which are framed together at the outer ends so as to work together. When lowered

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they rest on bed-plates on each side of the lock; a toggle-gear is provided for raising the tail end off the pivot.

The designing of these gates gave considerable trouble, as the conditions to be met are far from simple. The extra cost of the gate and masonry, and the complications in comparison with ordinary lock-gates, will not, in the Author's opinion, encourage the further adoption of the system, except for gates of similar or larger dimensions.

It was at first intended that the gates should be worked by hand; but as there will always be a difference of head of about 4 feet at the dam, it was decided to install a small turbine (Figs. 9, Plate 4) in a chamber in the dam (Fig. 7, Plate 3) for working hydraulic pumps capable of supplying 20 cubic feet per hour, and to move the gates by hydraulic power. Owing to the absence of data it is uncertain how much traffic will pass through the locks. The pressure-water, at 750 lbs. per square inch, is carried along the dam and across the lock in duplicate copper pipes to two accumulators of 16 cubic feet joint capacity (Fig. 7). Two accumulators were adopted, so as to reduce the height of the house, and also to have one always available in case of repairs. The capacity of each is equal to two complete movements of one gate. An automatic valve is arranged so as to stop the turbine when both accumulators are fully raised. Auxiliary steam-pumps are also provided in the accumulator-house, in case the turbine should break down.

The face-valves of the lock-gates are worked by four direct-acting rams, which are fitted with pistons arranged to make the return stroke when pressure is taken off the top side. Four valves, in addition to the twelve already mentioned, are provided at the bottom of the gate, in order to induce scour and to remove silt from the neighbourhood of the gate. These also are worked by direct-acting rams of similar design. The eight hydraulic cylinders are carried upon extensions of the gate, which are taken up through the carriage above the platforms. The extensions also convey direct to the gate the power required for travelling, and thus relieve the sling-rods from side strain.

The travelling-motion is worked by two hydraulic rams on the carriage, with multiplying steel-wire ropes which actuate a shaft carrying on each end a barrel, whereon are wound two ropes; one end of each rope being fastened to the fixed work at each end of the travel of the gate. Thus, if pressure is admitted to one of the rams, the travelling-rope on each side is hauled in, and the gate is moved in one direction; while, when the other ram is worked, the gate travels in the opposite direction.

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Each of the bascule girders is raised and lowered by a pair of rams, carried on the fixed girders, acting at the opposite ends of a lever keyed on the pivot on which the girders turn. A small double-acting ram works a toggle for raising the tail end of the girders, so as to give a proper bearing on each side of the lock, and also prevent the tail from being depressed by the first rollers which carry the load on to the bascule as the gate travels out.

The valves for working the hydraulic rams are piston-valves with leathers. Those for the sluices and for the travelling-motion are placed on the gate-platform, and water is conveyed to them by a walking pipe. For the bascule and toggle, the valves are on the abutment. An automatic cut-off is fitted to the travelling and bascule motions; and a buffer faced with hemp rope is fixed on the gate, to bring it to rest in its proper position when across the lock.

Bascule Bridge.

The roadway along the dam is carried across the top lock by means of a light bascule bridge (Figs. 10, Plate 4), having a span of 42 feet. The roadway is of timber, and is 11 feet 6 inches wide; four light lattice columns support the counterbalance arms, which lift the bridge by means of chains at the front end. At the back end they carry counterbalance weights and opening chains, by means of which two men can easily open each half of the bridge. A line of rails of 2-feet 6-inch gauge is laid across the bridge and along the roadway of the dam, for conveying passengers and material to and from the locks. A small workshop, with tools for carrying out repairs, is built on the east bank below the dam.

General Equipment.

In view of possible damage to the culverts, owing to the high velocity of discharge and the large quantity of rock débris in the neighbourhood of the dam, it has been thought wise to suspend grids, formed of heavy bull-head rails spaced 9 inches apart, in front of the culverts of the sluices at R.L. 87·50. The grids are hung by chains from brackets built into the dam just under the parapet. It was also thought prudent to provide a means of stopping up a culvert, should an obstruction prevent the sluice from being fully lowered. After much consideration, a curtain formed of heavy bull-head steel rails (Figs. 11, Plate 4) was decided upon. The rails are strung upon four steel-wire ropes, and have pieces of teak placed between them with rubber strips let in, so as to form a

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water-tight joint; the ends are also faced with rubber. The whole is wound on a shaft carrying two heavy cast-iron disks about 4 feet 6 inches in diameter. The top of the curtain when in use will be suspended from the brackets from which the grids are hung, and the curtain will then be lowered so as to unroll in front of the entrance to the culvert. The weight of the curtain complete is 18 tons. The surface of the masonry round the culvert-mouths is dressed about 2 feet back, which renders it possible to get a water-tight joint by means of the rubber on the curtain. A shield on the down-stream face will also be lowered into position; and the culvert will then be pumped out by two 6-inch centrifugal pumps placed on a hanging platform.

In order to handle these appliances, and also a small diving-bell for examining the dam and removing rocks from the culvert-entrances, a powerful steam-crane is arranged to travel on rails on the parapet. It will lift 20 tons at a radius of 25 feet, and is provided with air-compressor, small electric-light plant, telephone, etc. The water for its boiler and compressor is taken from a main laid along the dam, and kept supplied by a steam-pump near the first lock. The crane will also be useful for quickly lifting sluices out of the sluice-pits, should this be advisable for any purpose, such as painting.

For light loads a hand-crane is available, which can travel along the dam roadway. It can lift 1 ton at a radius of 36 feet, and will be handy for forming sand-bag sudds in or around the culverts. For dredging silt out of the lock-recesses, a steam water-lifter is to be used, so as to remove the silt by water-suction. In the upper lock-recesses, where a great depth of water has to be contended with, and where the silt may become about 2 feet deep without stopping the working of the gates, a grab will be employed.

When the reservoir is nearly empty, horizontal steel joists faced with timber will be placed across the lock, enabling all the gates to be drawn back into their recesses. The shutters will then be removed one by one, until a sufficient velocity is produced in the navigation-channels and locks to scour out any undue deposit which may have accumulated during the season.

Cataract Lock.

As the Nile narrows considerably below the dam, and the summer channels are much broken up by rocks, there is a surface fall of about 1·5 metre between the water at the lock-entrance

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and the river below the cataracts. Upon investigation, it was found that to blast a channel from the low-level water to the locks would be difficult and costly. An isolated lock is therefore being constructed in the western channel, about 1½ mile below the dam, at a point where a natural barrier of rocks renders the work comparatively easy. Owing to the configuration of the bed of the river, there will be at all states of the Nile a drop at the Cataract lock, and therefore the walls and gates have to be constructed so as to be above high Nile, and yet pass vessels at lowest low Nile; but at no time will there be a difference of head of more than 2 metres (6 feet 6¾ inches).

The gates are to be of the usual kind adopted in Egypt, namely, arranged each with two opening leaves, and provided with hand-sluices for locking-purposes. The opening- and closing-gear, however, is novel: it is arranged to be worked by one crab on the gate itself, with one closing- and two opening-chains wound on the crab-barrel.

The height of the lock is 9·5 metres (31 feet 2 inches), and of the gates 14 metres (45 feet 11 inches) and 13·5 metres (44 feet 3 inches) respectively.

Cast-iron grooves are arranged in the masonry for stop-timbers, in view of repairs being necessary, and also in order to afford a means of opening all the gates at once and allowing the lock-entrance and channel to be scoured out from time to time.

Erection of the Work.

Had not the time been so short, the erection of the sluices and lock-gates would not in itself have presented any unusual difficulties, as Messrs. Aird constructed alongside the dam a gantry from which the material could be picked up by cranes. Of course until the level of the culverts was reached, erection could not proceed. But as the masonry of each season's work was brought up to sluice-level about the same time for a considerable number of culverts, and as it was all-important not to delay the stonework, a large amount of forethought and organization was required. A further difficulty lay in the fact that, owing to the shortness of the season's work, it was impossible to keep the natives from one year to the next; and therefore the process of training unskilled men had to be gone through repeatedly.

In May, 1898, the Author visited the site of the dam, in order to arrange for the necessary storage-yard and other facilities. In

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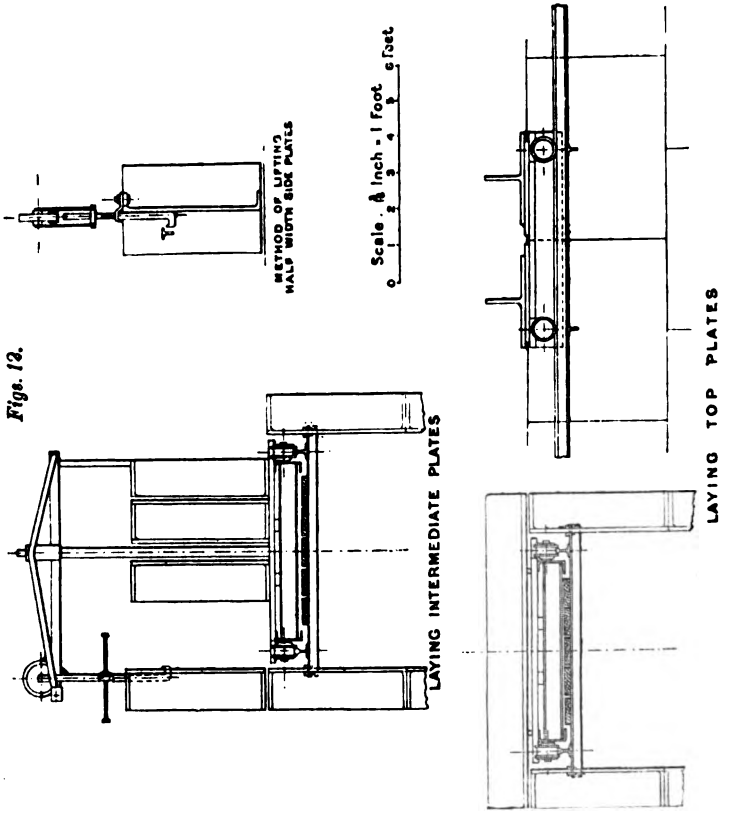
January of the following year he again visited Assuan, accompanied by Mr. E. H. Tabor, Assoc. M. Inst. C.E., who had been appointed their resident engineer by Messrs. Ransomes and Rapier, with Mr. G. S. Perry, Assoc. M. Inst. C.E., as chief assistant. The yard was quickly laid out, sidings were laid down, and offices and workmen's houses were built. The first sluice-material arrived in December, 1899; but the season's operations were practically



Figs. 12.

confined to storing material, and getting all in readiness for the following year. In the season of 1900, the period of erection was chiefly confined to about 8 weeks, but about 3,050 tons of culvert-linings, sluice-grooves, etc., were got in.

The erection of the culvert lining-plates was carried out by means of special plant arranged so as to stop the masons' work as little as possible; and the plates were therefore got into place from

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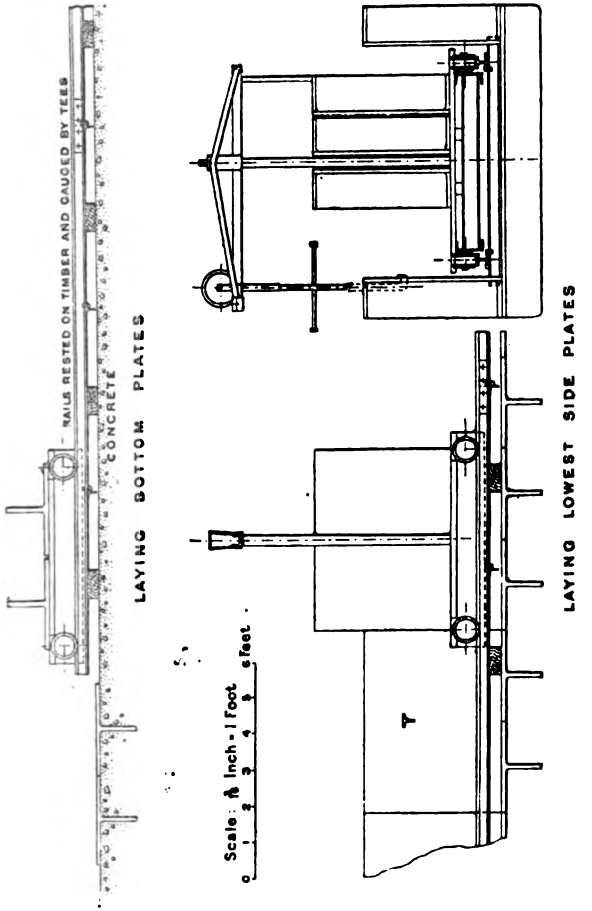
within the culverts. As already mentioned, T-struts were used for keeping each plate in its true position when fixed and bolted up; and on these struts planks and rails were laid. A trolley was provided for each culvert under construction, capable of carrying four plates placed vertically, two on each side of a centre pillar carrying an arm along which a simple screw lifting-


RAILS RESTED ON TIMBER AND GAUGED BY TEES
CONCRETE
LAYING BOTTOM PLATES
LAYING LOWEST SIDE PLATES
T
Scale: 1 Inch = 1 Foot
0 1 2 3 4 5 6 feet

Figs. 13.

tackle and roller travelled (*Figs. 12* and *13*). The level of the truck floor was a little below the top of the last tier of plates laid, so that each plate, on being lifted by a few turns of the screw-gear, could be travelled out quickly into position and lowered into place. The felt pads having been inserted, the four bolts were put

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in and tightened up. As each tier of plates was finished, more T-struts were inserted, and the platform and rails were transferred for the next operation at a higher level. The top plates were also got into place by sliding them off the trolley. A crane on the gantry kept the trolleys supplied with plates from trucks, brought up as required from the storage-yard.

In November, 1901, the first part of the 18-metre lock-gates arrived, and erection was at once proceeded with. The first gate took about 3 weeks to put together, and the second about a fortnight. The gates were erected in their recesses by means of derrick cranes, by which the material was picked up from the lock-bottom. When riveted up they were practically free from buckling, and therefore the diagonal bracing which had been provided as a precaution was not needed. As native riveters find it difficult to close $\frac{7}{8}$-inch rivets properly, a long-stroke pneumatic riveter was sent out for riveting the gates with a pneumatic holder-up. The bascule girders and carriages followed, and the hydraulic gear was fitted as soon as practicable. The first vessels passed the locks in August, 1902.

The first sluice was lowered in the presence of Sir Benjamin Baker and the Author in December, 1901.

It is greatly to be regretted that neither Mr. F. G. M. Stoney, who invented the form of sluice used in the dam, and who prepared the original outline scheme of sluices and lock-gates for Mr. Willcocks in 1894, nor Mr. R. C. Rapier, M. Inst. C.E., who took such a lively interest in the project, should have lived to see this great work put in hand. It is to be hoped, however, that the sluices will long remain a memorial of Mr. Stoney's inventive genius.

The Author desires to place on record the names of Mr. John Butler, foreman in charge of the lock-gate erection, and Mr. C. F. Turnstall, fitter, who both died at their posts from the effects of the sun, when the end of their duties was well in sight. These were the only two deaths connected with the erection, and the number of accidents was very small. This result was doubtless due in a great measure to the energy and skill displayed by Mr. Tabor in organizing and carrying out the work.

In conclusion, the Author wishes to express his thankful appreciation of the kindness and help received from Sir Benjamin Baker, more particularly when examining and passing the working-drawings and material for the sluices, lock-gates, etc. To Sir William Garstin, G.C.M.G., and the late Mr. W. J. Wilson, M. Inst. C.E., Director-General of Reservoirs, and his successor,

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Mr. A. L. Webb, M. Inst. C.E., his best thanks are due for their never-failing consideration and assistance; also to Mr. Maurice Fitzmaurice, C.M.G., M. Inst. C.E., and his successor, Mr. C. R. May, M. Inst. C.E.: while to Messrs. John Aird & Co. he is grateful for the cordial manner in which they have co-operated, so as to enable the work of erection to be quickly carried out, with the result that the dam has been finished and handed over to the Egyptian Government one season in advance of the contract date.

Praise is also due to Mr. R. H. Unsworth, works-manager of Messrs. Ransomes & Rapier at Ipswich, and to the staff working under him. During the season of 1900, the engineers determined to modify the programme of deliveries of work in England, with the result that 2 years' work had to be hurried through the shops in about 12 months. Thus the works had to be kept going day and night, fresh tools had to be laid down, and a severe strain put upon the energies of the workmen and staff, who all responded cordially to the call. That the completion of the dam was not in any way delayed for want of the sluices and lock-gates, is a fact well worthy of record.

The Paper is accompanied by drawings, from a selection of which Plates 3 and 4 and the Figures in the text have been prepared.

[Discussion.

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Discussion.

The President. The PRESIDENT, in proposing a vote of thanks to the Authors, remarked that the twentieth century was beginning well for engineering, with so early a record of such an important work as the Assuan dam. He congratulated Sir Benjamin Baker and Sir John Aird, and the members of their staffs, on the successful completion of the great and useful work which had been so well described in the two Papers read.

The Authors. The AUTHORS exhibited a number of lantern-slides illustrative of the work.

Sir John Aird. Sir JOHN AIRD, Bart., remarked that he was proud to have the opportunity of saying a few words in the Institution of Civil Engineers on the important work upon which his firm had been engaged. He desired first of all to congratulate the Authors upon the able Papers they had presented to the Institution. Having been associated with public works for a large number of years, he hoped he would be allowed to say that Mr. Fitzmaurice had been the right man in the right place—firm and determined, but at the same time always considerate. Mr. Fitzmaurice had given strength to those whose duty it had been to give effect to his wishes, and had supported them in their efforts. All connected with the undertaking must be thankful that in the early stages of the work there had been at hand a man of his power to carry it through. On one occasion, when the contractors had been pressed for time, Mr. Fitzmaurice had insisted on going down deeper into the rock, owing to its not being entirely to his satisfaction. The contractors had thought the work would be ruined, as they would be unable to complete it by the time desired; but Mr. Fitzmaurice had remained firm, and he had even gone so far as to ask them to wipe the stone with brushes and rags, in order to make sure of the soundness of the rock. At the time the contractors had thought this proceeding unnecessary and unwise; but they had altered their opinion. Mr. Fitzmaurice's wishes had been carried out, with the result that the work had justified the kindly remarks made by the late President of the Institution, Mr. Charles Hawksley, who had recently inspected it, and had been good enough to say that he had never seen a dam so free from permeation and leakage

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of any kind. He was proud to have had such a testimony from a Past-President of the Institution. On this point Mr. Fitzmaurice had been right, and he desired to acknowledge it. With regard to the work generally, the engineers on both sides had worked amicably together. In public works there were two sides to every question. The contractors had been pleased that, in the early stages of the work, thanks to the remarkable power of Lord Cromer and Sir William Garstin, who had studied the good of Egypt and the interests of the work from the beginning to the end, it had been agreed to leave everything to one man, Sir Benjamin Baker, a Past-President of the Institution; and Egypt had no reason to regret that decision. The contractors had not been quite in accord with Sir Benjamin on one or two occasions; they had perhaps had reason to regret some of his decisions; but, nevertheless, they had loyally bound themselves that any question which arose should be left to him, and he had decided to the best of his judgment, which was always sound and considerate. The work had been carried through from beginning to end without any hitch, and on handing it over there had been no outstanding differences at all. He wished to express in the Institution grateful acknowledgment to Sir Benjamin Baker for the desire he had always exhibited to do his duty in the delicate position in which he had been placed. The work itself had been highly interesting. The stone used in the building of the dam, was, as some of the Scotch masons sent out to Egypt had remarked, practically Aberdeen granite, and was easily subdued when dealt with by capable workmen. The bulk of the excellent men who had worked the granite had come from the North of Italy. They had earned good money, and it had been to the interest of the contractors to give them high wages. They had kept intent upon their work, and had carried it through successfully, giving their employers no trouble to speak of. But it should be remembered that in each branch of the undertaking the contractors had always been in advance of the requirements. That was an important point in the execution of public works: it was one of the secrets of the success of the enterprise; and it had been of immense help in working against time. The difficult work had had to be done during only 3 months of the year, when the Nile was low; and if the fullest advantage had not been taken of that time, the work would have been delayed, and instead of being completed, as it had been, in less than 5 years, it might have taken 15 years. The native population, the Fellahin, had also done their work well, better than the Sudanese.

Sir John Aird.

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Sir John Aird. Their anxiety to get the work done in time had almost equalled the contractors': the one feeling in their minds had been that the work must be done before the flood came. As for the contractor's own staff, the name of Mr. John Blue was one which ought never to be forgotten in connection with the works. Messrs. Aird and Company had received great credit, of which they were proud, and he would go so far as to say that Mr. Blue had been the means of bringing about the success which had been achieved. There were other names which ought also to be mentioned. Mr. Bakewell, Mr. Alessandrini an Italian, and others, had worked earnestly and hard in order to fulfil the contractors' promise made to the Khedive, to Lord Cromer, to Sir William Garstin, and to Sir Benjamin Baker, that every effort would be made to ensure completion of the work, not merely by the agreed time, but even, if possible, at an earlier date. Acknowledgment was due, also, to Messrs. Ransomes and Rapier, and to their representative, Mr. Stokes, who had carried out the sluice-works. As was well known, it was difficult to get a firm associated with the iron industry to do work within a stipulated time; and both engineers and contractors knew also that it was not an easy matter to get them to do it, even if a little longer time were allowed. But in Egypt, far away from the conveniences afforded at home, Messrs. Ransomes and Rapier had done their work thoroughly well: they had done it in less than the time allowed them; and by their efforts they had made success possible, where otherwise there would have been complete failure; because the contractors would have been ready for the ironwork, and the ironwork would not have been ready for them. Messrs. Ransomes and Rapier were entitled to that recognition; speaking from his knowledge and his experience in England, no firm could have done the work better, and none could have done it more quickly. He also wished to mention two names in connection with the engineering part of the work. At the commencement of the work, a great engineer, Mr. Wilson, the Director-General of Reservoirs, had been alive, and had taken an active part in the arrangements for the original contract. For 2 years Mr. Wilson had been spared to guide the contractors in their work, associating himself with Mr. Fitzmaurice in every possible way. His death had been a great loss to all who knew him, especially to those who had been associated with the Assuan reservoir; and the only feeling of regret on the opening day had been that Wilson was not present. Passing by that sad recollection—the only black spot associated with the work—another man, as the world knew, had come to fill the place of

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the man who had gone. Mr. Webb might have wished to be a "new broom" and to disturb some of the work done by his predecessor; but happily he was not so constituted; he was above that, and he had associated himself with Mr. Fitzmaurice and afterwards with Mr. May and Mr. Macdonald, who had succeeded Mr. Fitzmaurice; with the result that the work had been completed. The firm with which he had the honour to be connected, and on whose behalf he spoke, were proud to have been associated with a work so complete and so satisfactory to their employers, and one which it would always be a pleasure to recall. Sir John Aird.

Mr. Ernest Benedict remarked that, as one who had had a good deal of work to do in Eastern countries, he had been greatly harassed by Government insistence upon sanitary requirements. He had been struck with the wonderful health of all the employees in the great work described in the Papers. Therefore, if Mr. Fitzmaurice would state what sanitary precautions had been taken, both for natives and for Europeans, and how Europeans had managed to obtain sleep and keep in health under the intense heat, it would be of great use to engineers and others working in hot countries. He noticed in the Paper that one hundred men had been employed on sanitary work; but what had been their duties? Some years ago he had been engaged in erecting an extensive set of buildings in a hot and dry part of India, and the authorities had asked him what sanitary measures he proposed to take. He had replied that he intended to take none whatever; because the site had been a sandy plain away from any dwellings, and he had not seen the necessity for collecting matter which was much better dispersed, and which, wherever it happened to be deposited, was immediately worked upon by beetles and by the sun, and was thus disinfected much more quickly than it would have been when collected in trenches. The authorities had wished him to cut trenches and to insist upon the men using them; he had cut the trenches, but he had not been able to persuade the men to use them. Mr. Benedict.

Mr. F. E. Robertson observed that, in spite of the importance of the work, or rather, perhaps, because of it, there was little to discuss in the Papers; everything had been so well planned and so happily executed, that it was difficult to suggest any other way of dealing with the problem. It was stated at the beginning of Mr. Fitzmaurice's Paper that the country was rainless: in that connection he had had a rather amusing experience. When he had first gone to Egypt as President of the Railway Board, the railway from Keneh to Assuan had been under construction. On Mr. Robertson.

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Mr. Robertson. going up the line he had noticed that there appeared to be watercourses, but that no waterways were provided; and he had been informed that it never rained, and that the watercourses were antediluvian. Being new to the country, he had been unable to challenge that statement. In 1902 he had visited Egypt again, and had taken the opportunity to pay a visit to the Assuan dam. In most of the places where the line crossed the watercourses he had noticed deep holes. In one or two places where there had been bridges there were equally deep holes, but no bridges; the bridges had been completely swept away. Probably similar occurrences would be within the experience of other members—that at a certain place it was said that it never rained and a flood never occurred, but as soon as a line of railway was built, a flood immediately took place. He might perhaps throw some light upon the questions raised by Mr. Benedict in regard to sanitary arrangements. In a sandy, hot and excessively dry country the sanitation really took care of itself. It might seem incredible, but he could state from personal knowledge that the practical sanitation of many towns in Sind was to use the house-tops, nothing more; the intense heat dried up everything, and the inhabitants did not seem to suffer any evil effects. Mr. Stokes's description of the sluices had been made somewhat clearer by the lantern-slides, but his Paper certainly left something to be desired in respect of explanation of the action of the Stoney sluice. If Mr. Robertson had not known how those sluices worked, he thought he could not have understood from the Paper what the Stoney sluice was; and he suggested that Mr. Stokes should amplify some of the illustrations before his Paper was printed in the Proceedings.

Mr. Vernon-Harcourt. Mr. L. F. VERNON-HARCOURT thought every one would agree that the work described was wonderful, and that it had been carried out remarkably well. A dam in such a position must be carried down to very solid foundations, because, unlike any other dam with which he was acquainted, it had to allow one of the large rivers of the world to pass through it at full flood; he quite agreed with Mr. Fitzmaurice as to the desirability of getting down to the soundest rock that could possibly be found. It was interesting to learn that the pressure at the bottom of the dam was comparatively low. Though the dam was long, it could not be called high; and the problems of its construction were connected rather with difficulties of execution among cataracts, in a river like the Nile. He was pleased also to notice that sluice-gates sliding against free rollers were used with advantage where the sluices had at certain times to be opened against a considerable head of water. The

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credit of these sluices was due to the late Mr. F. G. M. Stoney, who had devised the system, and who, in association with Messrs. Ransomes and Rapier, had carried it out in various places, such as on the Manchester Ship Canal, and across the Thames at Richmond. One point had been touched upon only casually in Mr. Fitzmaurice's Paper, namely, the height to which the dam had been carried. Sir William Willcocks, on the occasion of the Glasgow Engineering Congress in 1901, had written a Paper on the Assuan dam, wherein he had looked forward to the time when the dam would be raised to about 6 metres higher than it was at present; and in his book, "The Nile Reservoir Dam at Assuan and after," published subsequently, he gave a cross section of the dam showing it thus raised; but it seemed unlikely that the decision arrived at with regard to the height would be reversed. No doubt the utility of the dam in regard to storage of water had been considerably reduced by the fact that it stored only about two-fifths of the quantity originally intended. Sir William Willcocks's original design—as might be seen from his report of 1893—was for a dam, not at the present site, but a little way above Assuan, with the object of avoiding the submersion of the temple of Philae; and he had originally proposed to Sir William Garstin two schemes, both above Philae, one for storing up 3,733 million cubic metres of water to R.L. 118 at a cost of £2,100,000, the other for impounding water to R.L. 115, with a reservoir having a storage-capacity of 2,792 million cubic metres, at a cost of £1,770,000.[1] After carefully considering the matter, Sir William Garstin had reluctantly decided against the site suggested. Its great advantage was that there would have been no trouble about the submersion of Philae; but the objection raised by Sir William Garstin had been that the foundations of the dam would be so much below the summer water-level, that there would have been great difficulty in carrying out the work, the site being above the main cataracts. Then Sir William Garstin himself had presented three schemes for forming a reservoir, by a dam at Assuan, at different levels, very similar to some schemes alluded to by Sir William Willcocks in his report,[2] though he had given a decided preference to the site above Philae. The schemes suggested had been:—(1) For a dam holding up the river to R.L. 118, and impounding 3,700 million cubic metres of water, at a cost of £1,900,000, which Sir William Garstin had

Mr. Vernon-Harcourt.

[1] "Report on Perennial Irrigation and Flood Protection for Egypt," W. Willcocks, pp. 22 and 24. Cairo, 1894.

[2] *Ibid*, p. 36 and Appendix VIII., pp. 18 to 23.

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Mr. Vernon-Harcourt.

thought at that time would suffice for the irrigation of the whole of Egypt. (2) A dam retaining the water to R.L. 114, storing 2,550 million cubic metres, at a cost of £1,600,000, for supplying Middle and Lower Egypt: this scheme had been preferred by Sir William Garstin. (3) A dam holding up the river to R.L. 110, with a capacity of 1,600 million cubic metres, at a cost of £1,300,000, which would have served for the irrigation of Lower Egypt only.[1] In all these schemes £200,000 were added to the estimates to cover the cost of removing the temple of Philae to Bigeh Island. The second proposal, which was a modification of one of the designs investigated and estimated for by Sir William Willcocks in his report of 1893, was the scheme which had been submitted to the Commissioners and approved with slight alterations. Sir William Garstin also stated in his note that if the removal of the temple of Philae to Bigeh Island were not sanctioned by the Egyptian Government, it would be necessary to abandon the Assuan site altogther, and to build the dam at Kalabsha, 30 miles higher up the river. That site had not been approved by the Commission, who had considered Assuan to be the only suitable site for the dam north of Wadi Halfa; and therefore it had been decided to carry out the second scheme at a cost of £1,600,000. The finished dam was 26¼ feet lower than had been intended originally, owing to the archæologists, who had objected both to the rebuilding of the temple on a higher site, and to its partial submersion; and thus the utility of the work was greatly diminished. It had provided a reservoir with a capacity of only 1,065 million cubic metres, which would be altogether insufficient for the wants of Lower Egypt alone, estimated by Sir William Garstin at 1,600 million cubic metres. He would like to know why the cost as estimated by Sir William Willcocks in 1901, for the works as carried out with their deeper foundations, differed so widely from the actual cost. In his Paper at the Glasgow Congress, Sir William Willcocks had expressed the opinion that if the work had been done by Government agency, the dam could have been carried to its finally-proposed height of R.L. 112 for £1,750,000; or, making allowance for the reduction in height of the present dam, £1,500,000 for the work as actually carried out,[2] instead of £2,450,000. Sir William had hoped at that time

[1] "Note on Perennial Irrigation and Flood Protection for Egypt," W. E. Garstin, pp. 24, 28, and 52. Cairo, 1894, .

[2] International Engineering Congress: Glasgow, 1891; Proceedings of Section II., Waterways and Maritime Works, "Irrigation in the Nile Valley, and its Future," W. Willcocks, p. 48.

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Mr. Vernon-Harcourt.

that the dam would be raised to R.L. 112, at a cost of £250,000; which would have doubled the capacity of the reservoir. Mr. Fitzmaurice said that no silt came down the Nile at the time when the operation of filling the reservoir took place. That was only partially correct, because in a Paper [1] on the River Nile, written by Sir Benjamin Baker in 1880, it was stated that in the month of November 4,000,000 cubic metres of solids came down in suspension, in December 2,000,000 cubic metres, in January nearly 1,000,000 cubic metres, and in February about 500,000 cubic metres; therefore there was a decided prospect that silt would gradually accumulate in the reservoir. No doubt it would take a long time to accumulate to any serious extent; but if, as had been suggested at the opening ceremony, the dam was to be a monumental work which would keep up, for all time, the remembrance of the British occupation of Egypt, the question of silt would eventually crop up in, say, 100 years, even on the basis of the figures given. He considered it was extremely regrettable that the dam had been lowered. He understood that what was specially required in Egypt was the certainty that a definite amount of water would be obtained for summer irrigation, whether the Nile was very low or not. Sir William Willcocks had formerly put the figure at 500 cubic metres per second. Some time ago he had worked out what the flood in the low Nile of 1878 would give, and had estimated that the flow of the river during its low stage, together with the Assuan reservoir as constructed, would give about 370 cubic metres per second, instead of the 500 metres which Sir William Willcocks had originally hoped to get from the dam when he designed it; and the available discharge would fall considerably below this at the low stage of the river in such a low Nile as that of 1900. The work having been completed, it seemed very desirable that search should be made for some other source for providing the water necessary for summer irrigation, which unfortunately had not been provided—not owing to any fault of the engineers or the contractors, who had carried out their work well, but owing to the archæologists who, in an unfortunate moment, had persuaded the Egyptian Government to lower the dam. Sir William Willcocks had recently stated that 5,663 million cubic metres of storage would be required for the perennial irrigation of the Nile valley below Assuan [2]; and Mr. Fitzmaurice had alluded in his Paper to the possibility of storing 5,000 to

[1] Minutes of Proceedings Inst. C.E., vol. lx. p. 373.

[2] W. Willcocks, "The Nile Reservoir Dam at Assuân and after," p. 2. Lond., 1901.

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Mr. Vernon-Harcourt. 7,250 million cubic metres of the flow of the Nile. He believed there were only three sites available. Possibly there would be sites south of Wadi Halfa for reservoirs similar to that at Assuan; but the Commissioners had stated that there was no site other than Assuan, for a reservoir north of Wadi Halfa. There were only two other possible sites, if the Nile would not serve above Wadi Halfa; the one was one of the equatorial lakes, Lake Albert, and the other Lake Tsana in Abyssinia, with regard to which a treaty had been published towards the end of 1902. The latter lake was about 4,481 feet above the Nile at Khartum; and the distance was about 760 miles, along the Blue Nile, from the lake to Khartum. That gave an average fall of 5·9 feet per mile from Lake Tsana to Khartum; and Sir William Willcocks said the fall of the Blue Nile was very regular. The Albert Nyanza was about 777 feet above the Nile at Khartum, and was 1152 miles from that town, by the White Nile. Hence there was a fall of only 8 inches per mile from the lake to Khartum. Unfortunately, also, in some parts of the White Nile, which, with Lake Albert, would be otherwise much more desirable as a source of supply, because it was within the British sphere of influence, the fall was only about 2½ inches per mile; and the channel was also considerably impeded by the "sudd," which had been only partially removed; the water was largely dispersed among swamps. It therefore seemed to him that the most suitable site which could eventually be obtained—and probably the treaty with the Emperor Menelik would help towards that end—was Lake Tsana, which, on being raised only about 15 inches, would give as much storage as the existing dam at Assuan.

Mr. Upcott. Mr. F. R. UPCOTT wished, in the interests of India, to ask Mr. Fitzmaurice if he could supplement the Appendix to his Paper, referring to the mortar used in the hearting of the dam, mentioned at p. 87. He understood that the lime and burnt clay which had been used had proved highly successful, but that in the absence of sufficient fuel for burning the clay the engineers had been obliged to have recourse to 4-to-1 cement mortar. In India practically only two kinds of mortar were used, one, lime and burnt clay, which latter was called surki, and the other made of kunkur lime: both were more or less hydraulic. As a rule, coal was not available, and bricks were burned with wood fuel. He imagined there was no fuel anywhere near the Assuan dam. If, in addition, Mr. Fitzmaurice could supplement the Appendix by giving the results of any tests of adhesion on the granite, they would be of great interest to engineers in India. He would also like to know

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whether, in the tensile tests, the mortar had been put under water before carrying out the experiments. At the bottom of p. 107 there was a reference to the cubes in connection with the compression test, but it was not stated whether the tensile tests also applied to mortar which had been kept under water. The average strength of 160 lbs. per square inch after 28 days was exceedingly good. As a rule, in India, not much more than 140 lbs. per square inch was obtained. The compression tests, also, showed a high average result; but it would be useful if the results were all stated in pounds per square inch, both for tenacity, crushing-strength and adhesion. Mr. Upcott.

Sir BENJAMIN BAKER, K.C.B., Past President, thought that, apart from technical reasons, the successful completion of the Assuan dam was a subject of interest to British engineers, because it typified the work which had been done by their colleagues for many years past in Egypt, and which had received little notice at home. Naturally, as was well known, in Ismail's time the Public Works Department had been starved, and the French engineers in charge had not really had a free hand to do what they would like. As a consequence, after the British occupation the first work of the English engineers had been to endeavour to bring into use the works constructed by the French engineers, which had either been left in an unsatisfactory condition—like the great Nile barrage at the apex of the delta—or had been imperfectly maintained. It had naturally taken a good many years to carry out those necessary but unobtrusive works; and from his own knowledge he could say that many of them had involved nearly as much anxiety as the Assuan dam. They had been carried out often under extremely trying climatic conditions, the engineers working day and night in the hottest time of the year, watching the canals and regulating the works upon which depended the fertility of many hundred square miles of country. All those works had been carried out without any recognition or notice at all except among the engineers themselves. He had always been struck by the good fellowship among the Public Works engineers and their loyalty to each other; and he thought it was extremely satisfactory to know that British engineers—members of the Institution—had carried on their difficult work in Egypt without seeking publicity or recognition from any one in England, and asking no more than the appreciation of their colleagues. Engineers at home ought to congratulate them on having finished at last something which must be noticed by the whole world. No one could now make the taunt, which the Sir Benjamin Baker.

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Sir Benjamin Baker.

enemies of England in Egypt had made a few years ago, that all that British engineers had done in Egypt had been to maintain the works constructed by Frenchmen. Looking at the Suez Canal, the Ibrahimia Canal, and the great Nile barrage at the apex of the delta, that might be plausible; but now the Assuan dam had been completed by the Public Works Department of Egypt it was otherwise. When taking leave of him recently the Khedive had said to him, "What have my ancestors done?—the barrage of the delta; what is that in comparison with this Nile dam?" That, he thought, would be the general verdict of the public. The dam, as might be judged from the photographs which had been exhibited, was a most impressive work. In money, of course, and in cubical contents it represented but a fraction of the Suez Canal; but no one who had seen the two works would compare them for a moment in impressiveness. The Assuan dam was infinitely more impressive, and more likely to be known throughout the whole of the civilized world, than even the Suez Canal, or any other French work in Egypt. For that reason he thought, as brother engineers, the members ought to congratulate the Public Works Department on having at last obtained their reward for the dozen or more years' anxious work which they had been carrying on quietly and unobtrusively, without recognition from the public. Another reason why English engineers ought to be interested was that for many years past it had been Lord Cromer's ambition to build the dam. Lord Cromer had said to him recently, "Of course my difficulty was, which should I tackle first—the Sudan or the Nile Reservoir? And then I said to myself, I will do both, and make one pay for the other." That was like Lord Cromer; he had courage enough for anything, and patience enough to bide his time until opponents were tired out. But the point he particularly desired to emphasize was that Lord Cromer had chosen British engineers for his right-hand men and helpers in Egypt. His chief Secretary of State, Sir William Garstin, G.C.M.G., was a civil engineer; and so with the others. In carrying out the great work he had done for Egypt; in raising its funds from the very low ebb at which they had formerly stood to the high position which they now held—so that they were even more stable than British Consols—Lord Cromer had availed himself throughout of the services of engineers as advisers and administrators. He was afraid, from his experience and recollection of the last 30 or 40 years, that at home the tendency of the great companies in later years had been to regard the engineer merely as a bit of a mathematician, and a master of certain text-books, but not as a man to be consulted

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on questions of high policy in regard to the initiation of works or their administration: those questions were to be dealt with by the chairman and directors, in consultation with the general manager, while the engineer was a kind of technical officer, subject more or less to the general manager. That state of affairs had not obtained in England in earlier days, and he did not think it was justified now; because an engineer, if he was experienced and worthy of his calling, was a great deal more than a bit of a mathematician or a master of technical knowledge. He must have a general knowledge of men and business, in addition to possessing the other necessary qualifications, such as sound judgment on all matters. The engineer had technical knowledge and mathematics in addition to the qualifications which the untechnical man had. If it were contended that that was theory and not practice, he would point to Egypt, and would ask whether any commercial undertaking could be mentioned which had made such enormous advances as had Egypt under Lord Cromer, with engineers as his right-hand men and advisers. He had been delighted at the announcement made that evening that the Institution intended to do itself the honour of electing Lord Cromer an Honorary Member. Lord Cromer thought well of engineers, and he was sure every British engineer thought well of Lord Cromer. Sir Benjamin Baker.

With regard to technical points, he might, of course, enlarge on them to any extent. He desired to give one word of caution, namely, neither contractors nor engineers should assume that they would necessarily always have the same good fortune as the present contractors and engineers, if they undertook a similar work. He referred especially to the good fortune experienced in getting in the foundations. He well remembered Sir John Aird's solemn face when, on first seeing the cataract pouring down and the nature of the rock on each side, he had exclaimed, "What have I let myself in for now?" It had not been a case of building a dam on dry land, but of building it across cataracts such as those shown in the photographs exhibited. It had been impossible to tell the nature of the bottom of the river. Divers could not be sent down into a river running at 15 miles per hour. All the information which could be obtained by probing and in other ways was that the material was the same below as on the bank. He remembered going on one occasion up the side of the cataract, where the boulders were so large and the interstices between them so wide that in many cases instead of climbing over the boulders he had lain down on his stomach and wriggled through

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Sir Benjamin Baker.

the interstices. That was not very promising material with which to make a water-tight dam. There had been no clay anywhere near, and nothing at hand but sand-bags with which to do the work. The rock had all been fissured, and, as far as it was exposed, the fissures had been absolutely clear of any filling material. The question had been—what was the probable condition of the fissures down below, out of sight, and how deep would they extend? Such matters had been purely problematical until the water had been got out and something could be seen. He had done the best he could. Sir Archibald Geikie, the Director of the Geological Survey of Great Britain, had been extremely kind, as he always was. He had collected his staff, who had been making the geological survey in the Highlands, where there was a good deal of granite, and they had studied the fissures. A consultation had been held, and the prospect of the condition of the fissures at Assuan had not been encouraging. In most cases the fissures in the granite of the Highlands were filled with light material which was easily washed out by water under pressure; and therefore it could easily be imagined that had a similar state of things obtained over the area covered by the dam, all the pumps in Egypt would not have kept the water down. The first thing he had done after the consultation had been to ask Sir John Aird to send out twenty-four instead of twelve 12-inch direct-acting centrifugal pumps for the first channel, which, like everything else suggested to him, Sir John had done at once, regardless of cost or any other consideration. The twenty-four pumps had been provided to work on the smallest channel; but it had turned out that the fissures there were filled with practically impermeable material, and the leakage had been found to be so small that only two pumps had been required to keep it down. He had never had such an experience before, though he had had to deal with similar rock in getting in bridge-piers, where he had had to crowd on more pumps for getting the water out of a small coffer-dam than out of one of the big channels of the Nile. That circumstance had been the salvation of the whole work; but for it the plans would have had to be completely altered, and the dam would not have been finished for 2 or 3 years to come. Of course the engineers had considered what they would do if they could not get the water out; and Mr. Wilson (who was now sleeping in the English churchyard at Cairo), and he had spent night after night together, scheming ways of dealing with the problem, by compressed air and otherwise. It might happen that the next contractor and the next engineer who started upon a similar work would find

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Sir Benjamin Baker.

that the fissures were not filled with impermeable material, and then a very different tale would have to be told. The cost would have to be doubled, and the time perhaps more than doubled. Therefore it was a necessary caution not to rely in other cases upon having the good luck which had been experienced in the present instance. He would not trouble to answer the questions raised in the discussion, because Mr. Fitzmaurice was even more familiar with the work than he was; but the members would understand that the design of a dam was a simple thing. A student at an examination might design the cross section of a dam; but it was quite a different thing to have to carry it out, considering the anxiety, the pressure of work, and the climatic conditions. He could not express too highly his appreciation of the services and the zeal of the late Mr. Wilson, Mr. Webb, Mr. Fitzmaurice, Mr. Blue, Mr. Tabor, and all the engineers. Many of them had been unable to sleep at night because of the intense heat, but they had never allowed that to interfere with watching every detail and varying the design according to the altered conditions—matters which did not bother an engineer when he was working with a sheet of paper. It was when he was actually carrying out the design, and when he was personally responsible for the work, that the engineer really began to feel the strain; just in the same way that being the subject of a surgical operation was very different from telling some one else to undergo it. For that reason the engineers and contractors who had been engaged on the work ought to receive the thorough appreciation of all at home. The Home contingent which had gone out to help the Public Works Department had been, after all, only temporary assistants; the building of the dam was the Department's undertaking, and the Home engineers, including himself, had been merely temporarily aiding them; and they had been only too pleased that their services should be given to such thoroughly good colleagues as those in Egypt. The Home engineers had left, and were going about their other business, but those of the Public Works Department were still responsible, and had not seen the end of their anxieties, because the working of the dam had to be looked after. It remained to be seen what would happen in the way of silting; what difficulties might occur in consequence of loose rocks being washed down against the sluices and lock-gates which had been so ably designed by Mr. Stokes; and what the effects of the water rushing out of the sluices would be on the bed of the river below the dam. All those responsibilities and anxieties were upon the shoulders of the engineers of the Public Works Depart-

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Sir Benjamin Baker.

ment, who were the originators of the dam; and he acknowledged that they, with Lord Cromer at the head and Sir William Garstin, deserved the bulk of the credit.

Mr. Fitzmaurice.

Mr. FITZMAURICE, in reply, observed that, as mentioned by Sir John Aird, the great difficulty had been in getting the work in the channels completed before the Nile flood. He had quite realized the risk run, as regarded completing the work in each channel in the season, when it had become necessary to carry the excavation so much deeper than anticipated. That risk, however, he had always refused to consider, when it was set against the risk of founding the dam on rock not absolutely sound. The principal things which had enabled the work to be completed before the contract time were the exceptionally low Niles which had occurred for two consecutive years, and the excellent preparations which the contractors had made, in regard to both plant and materials, which had allowed them to take full advantage of these low Niles. With reference to the large number of men employed on sanitary work, he might say that a large number of Europeans had been connected with the work, and for them earth-closets had been provided. As regarded the native population, the hot sun was the principal sanitary agent. In answer to Mr. Upcott's questions, he had stated there was no fuel to be obtained near Assuan. All lime and clay had been burned with coal brought from England. In the tensile tests of the lime and clay mortar, the briquettes had been kept for 7 days under a damp cloth, and had then been placed in water until the time of testing. He was sorry no adhesion-tests had been made. Mr. Vernon-Harcourt had referred to the great difference between the estimate of the cost of the dam made by Sir William Willcocks and the actual cost. The cause of this difference was the large increase in the quantities of excavation and masonry, owing to the greater depth to which it had been necessary to carry the foundations on account of the bad rock met with: the fact that no granite masonry had been built in Egypt previous to the construction of the Assuan dam had also, no doubt, made it difficult for Sir William to form a satisfactory estimate. He did not think the work would have been carried out more cheaply if it had been done by Government agency. There certainly was a small amount of silt in the Nile when the filling of the reservoir began, but the amount which could be deposited in the reservoir during December and January was not worth considering.

Mr. Stokes.

Mr. STOKES, in reply, remarked that there were few points raised in the discussion which bore upon the subject of his Paper. He

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Mr. Stokes.

was exceedingly obliged to Sir John Aird for his complimentary remarks as to the way in which the work undertaken by Messrs. Ransomes and Rapier had been carried out. In a great work of the kind, there were difficulties of both an engineering and a commercial character to be overcome. To those responsible for the proper ordering of raw materials, and the supervision of the hundred and one things which went to ensure punctual completion of a job in a distant country, credit should be given also, and the firm's secretary, Mr. A. Aly Bennet, should be mentioned as having contributed towards the successful carrying through of the contract. He would like to join with Sir John Aird in his tribute to the memory of the late Mr. Wilson. Referring to Mr. Robertson's suggestion that the principle of the Stoney sluice might be further explained, the action was so simple that there was really little to add to the Paper. The sluice itself might be of any convenient construction to suit the size of opening and head of water. On each side of the sluice, on the face away from the head of water, a roller-path was formed having a machined face. A corresponding roller-path face was provided on the fixed groove built into the masonry. Between these two faces a number of rollers were hung, arranged in a frame so that they were kept true, and in their proper relative positions. When there was a head of water against the sluice, the force was transmitted by the rollers direct from the sluice to the fixed roller-path, and the sluice could be raised and lowered with ease, as the friction to be overcome was only a rolling friction. It would easily be seen that the rollers travelled at only one-half the speed of the sluice, and in order to hang them in their proper position, while allowing them to roll at their proper speed, the cradle containing the rollers should be arranged to move at this relative speed. The roller-frame was therefore hung on to a two-part rope or chain, one end of which was fixed to the masonry and the other to the sluice. The greatest accuracy was required in the size and truth of all the parts, so that the rollers took their proper relative loads. He fully concurred with the remarks of Sir Benjamin Baker. The designing of the sluices and lock-gates had required a great deal of anxious thought and scheming; and it was highly satisfactory to find that so far, at least, all the sluices and lock-gates were working perfectly. In a work of this magnitude there had of necessity been several persons engaged on the designs, and although he had been responsible for the work, he did not wish it to be thought that he claimed all the credit for the way in which the designs had

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Mr. Stokes. been prepared or the work executed. The early completion of the contract had been rendered possible by a lucky succession of favourable seasons, and by the hearty co-operation of all concerned.

Correspondence.

Mr. Binnie. Mr. W. J. E. BINNIE remarked that in a foot-note to p. 75 it was stated that all reduced levels were referred to heights in metres above mean level of the Mediterranean Sea. At the port of Alexandria a datum existed on the locks of the Mahmudie Canal, which was extreme low-water of the Mediterranean, and was used as a reference for bench-marks in that neighbourhood. This was the datum marked "Ordnance Bench Mark" on the chart of the port dated 1898. It might be of interest to mention that this datum was 0·31 metre below the mean minimum tidal level of the Mediterranean, as shown by the readings of the mareograph established at the end of the inner mole of the port. The datum in question was the only one in existence at the port of Alexandria, and he had recently had to investigate this question in order to establish a high-water level for the new graving-dock constructed for the Khedivial Co. The high-water level had been ultimately fixed at 0·53 metre above the datum, that being the average maximum tide-level throughout the year. The average tidal variation at Alexandria would therefore be 0·22 metre, and the mean level of the Mediterranean would be 0·42 metre above the above-mentioned datum. Apparently some other datum, perhaps taken from levels established for the Suez Canal, must exist, as no mean tidal level at Alexandria had been established; and he thought it would add to the value of Mr. Fitzmaurice's Paper if the origin of the datum used at Assuan were more clearly defined; for if two different datums were in use in Egypt confusion must arise. He would also like to know whether any difficulty had been experienced at Assuan from too rapid setting of the Portland-cement mortar.

Sir R. H. Brown. Sir R. H. BROWN, K.C.M.G., considered that Mr. Fitzmaurice's Paper was so complete and lucid as a technical description of the construction of the work, and the projected method of handling it, as to require nothing but Mr. Stokes's Paper to supplement it. But in the concluding sentence of his Paper, Mr. Fitzmaurice referred to the anticipated effects of the work in words that seemed to

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encourage a popular delusion. He described the work as "destined to increase the wealth of the country, and to lessen the great anxiety with which the rise of the Nile has been regarded in past years, since on this it depended whether the year was to be one of plenty or one of famine." It was quite correct to say that the work was destined to increase the wealth of the country; but the rest of the sentence gave the reservoir credit for producing effects which had not been contemplated in the project for the construction of the Assuan dam. The uninitiated might conclude from the sentence quoted that the Nile flood in Egypt below the reservoir would be affected by the construction of the dam. It was a common delusion that the dam would give in future the power of moderating high floods, and of improving low floods. It gave no such power, and had no effect on floods in Egypt: its function was to give a better supply than had hitherto been available in summer, so that the cultivation of sugar-cane and cotton might be increased. These were not the food-crops of the people; and, although the expression "plenty" was in a sense connected with them, it was not connected in its special sense as opposed to famine. Famines in Egypt had been out of date before the Assuan dam was made. There had been no famine in 1899, but only local scarcity in unfavourably situated lands; and these lands would be no better off than they had been before the reservoir was made. The only difference the Assuan dam would make to the flood would be that the river immediately above it would be 2 to 3½ metres higher than before: the volume of the flood flowing forward would be unchanged. Mr. Fitzmaurice stated clearly enough what the dam would do; but the misconception about its influence on the flood was so widespread that it seemed necessary to state also what it would *not* do. It might be of interest to mention the following facts regarding the first use made of the dam. The flood of 1902 had been very poor in quantity and quality. Its levels had been low, and the quantity of matter carried in suspension comparatively small; consequently, it had been considered advisable to commence filling the reservoir at an early date. The closing of the first gates had been begun on the 20th October, 1902, with the following water-levels:— Sir R. H. Brown.

Up-stream of the dam	R.L. 94·90
Down-stream ,, ...	R.L. 90·30

The first operation of closing had been letting down the fifty sliding gates. The gradual rise of the water-level in the reservoir

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Sir R. H. Brown. had followed, and on the 10th December, the date of the inauguration of the dam, the levels had been :—

Up-stream of the dam	R.L. 103·59
Down-stream „	R.L. 87·15

On 26th January, 1903, the levels had been :—

Up-stream of the dam	R.L. 105·91
Down-stream „	R.L. 86·06

and the full up-stream level of R.L. 106 would be reached by the end of the month.

Mr. Carew-Gibson. Mr. H. F. CAREW-GIBSON observed that the difficulty of estimating what the surface-gradient of the full reservoir would be was no doubt due in a large measure to the prevailing wind, which was a northerly one, and consequently tended to back up the water, as it blew up-stream; but as this was an important matter, affecting as it did in no small degree the capacity of the reservoir, it would be of great interest if Mr. Fitzmaurice would state what the gradient was found to be. The reservoir was now full, or sufficiently so to render it possible to obtain this information. Careful levels had been established for a considerable distance up-stream of the dam. With regard to the setting-out of the work, Mr. Bakewell, who had been chiefly responsible for this, had had a much harder problem to face than might be supposed from a glance at Fig. 3, Plate 1, owing to the climatic conditions and to the fact that it had been impossible in such rough country to find level ground near the cataract on which to measure a long base-line. In spite of this he believed that when the dam had been closed, and it had been possible to get a direct measurement through, there had been found to be only a possible error of 11 centimetres in the 2,000 odd metres; a result which entitled Mr. Bakewell to great credit. With regard to the burnt clay and lime mortar spoken of in the Paper—known locally as "homera" —this, or something like it, seemed to have been used both by the ancient Egyptians and by the Romans in all their large buildings throughout Egypt; and it showed as fresh in some of these at the present day as if it had been placed there only within the last few years, instead of at least 2,000 years ago. This in itself proved that the material had some good qualities. He believed that at Assuan, and in fact all over Upper Egypt, no pure clay existed, and for this reason it had been found difficult to manufacture satisfactory bricks; but, apart from such reasons and those of cost, he thought Mr. Fitzmaurice had been well advised in using Portland-cement mortar, as it appeared to him that when it set

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"homera" had a tendency to shrink away considerably from any large stones bedded in it, and that it had no great adhesion to granite. It had been found to form a strong mortar for brickwork, and no doubt the same would be the case when it was used with any porous rock, such as sandstone. The great trouble at Assuan had been to keep the granite and green masonry well watered; for under such a fierce sun all moisture had evaporated very rapidly. At first rush mats from Lower Egypt had been used to cover the new work; but it had soon been found that when these had been wetted the water ran off from them much the colour of pea-soup, and it had been feared that this green water might have some harmful action upon the cement: canvas had therefore been substituted, and had answered its purpose well. A temperature-chart added to the Paper would be of interest. Mr. Carew-Gibson.

Mr. W. DYCE CAY pointed out that as the water from the reservoir was conveyed to the irrigated lands of Egypt in the ordinary low-water channel of the River Nile, it would be subject to great loss from evaporation in a dry climate. With a view to appreciate this loss he had prepared the accompanying Table (pp. 144 and 145) from the Egyptian Government Meteorological Reports for 1902. It would be seen that, taking Assuan and Asyut together, the average evaporation at these places was in May 14·9 millimetres and in June 15·35 millimetres per diem; also the reports showed that in the first 7 days of July it was 14·5 millimetres, making an average evaporation of, say, 15 millimetres per diem for the 68 days of the year mentioned in the Paper as the period when, in an ordinary year, the contents of the reservoir would be run off to feed the river. The Table also showed that climatic conditions for a high rate of evaporation, namely, high temperature and low relative humidity, existed up to Khartum and beyond it. Supposing a length of river channel of 2,300 kilometres, with a width of 1,300 metres, and an evaporation of 15 millimetres per diem for 68 days, there would be evaporated in that time, say, 3,050 million cubic metres, or nearly three times the contents of the reservoir, which was stated at 1,065 million cubic metres. Again, taking the distance from the reservoir at Assuan down the river to Asyut at 480 kilometres, and the other data as before, the quantity evaporated between these places would be, say, 636 million cubic metres. While considering the reservoir system to be the best for compensating such losses, he thought it possible that local study might discover advantages to be gained by regulating the low-water channel of the river, so as to reduce the areas on which the evaporation would have most effect, and so Mr. Dyce Cay.

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TABLE OF EXTRACTS FROM METEOROLOGICAL OBSERVATIONS MADE IN THE YEAR 1902 BY THE EGYPTIAN PUBLIC WORKS SURVEY DEPARTMENT.

—	Place of Observations.	Latitude. North.	Distance from Victoria Nyanza.	March.			April.			May.				June.			
				Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.	Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.
		° ′ ″	Kilometres.	°C.	Per Cent.	Mm.	°C.	Per Cent.	Mm.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.
1	Giza, Cairo .	30 01 57	4,790	..	..	..	..	..	..	23·0	56	drops	..	24·5	58	0	..
1a	Abbassia, Cairo	30 4 36	4,790	..	..	..	..	..	..	23·9	47	drops	8·1	25·8	50	0	6·4
	Asyut . . .	27 11 0	4,430	..	..	..	..	..	..	27·2	26	0	14·1	28·8	26	0	15·5
3	Assuan . .	24 2 25	3,950	..	..	..	..	..	..	32·3	16	0	15·7	32·4	20	0	15·2
4	Wadi Halfa .	21 54 49	3,580	..	..	..	..	..	..	30·6	20	0	..	31·0	23	0	..
5	Berber. . .	18 1 0	2,480	..	..	..	29	12	0	34·8	14	0	..	34·7	18	0	..
6	Khartum . .	15 38 20	2,130	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6a	Omdurman .	15 38 20	2,130	28	14	0	31	13	0	34·1	19	0	..	33·1	27	0	..
7	Wad-Medani .	14 24 0	2,010	..	..	..	..	..	..	33·3	23	5·6	..	31·6	34	53	..
8	Ducm . . .	14 0 0	1,970	..	..	..	..	..	..	32·7	25	36·0[1]	..	30·6	36	0	..

NOTE.—The daily mean temperature is deduced from the formula $\frac{8h + 14h + 20h + m}{4}$ in the cases of Giza, Abbassia, Asyut in August, September and October, Assuan, Khartum, Omdurman in May and June; the other daily mean temperatures and all the relative humidities are deduced from the formula $\frac{8h + 20h}{2}$.

[1] In one day.

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TABLE OF EXTRACTS FROM METEOROLOGICAL OBSERVATIONS MADE IN THE YEAR 1902 BY THE EGYPTIAN PUBLIC WORKS SURVEY DEPARTMENT—*continued*.

—	Place of Observations.	Latitude. North.	Distance from Victoria Nyanza.	July.				August.				September.				October.			
				Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.	Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.	Mean Temp. Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.	Mean Temp Dry Bulb.	Relative Humidity.	Total Rainfall.	Evaporation per Diem.
		° ′ ″	Kilometres.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.	°C.	Per Cent.	Mm.	Mm.
1	Giza, Cairo .	30 01 57	4,790	26·0	61	0	..	25·9	67	0	..	24·6	74	0	..	22·7	75	0	..
1a	Abbassia, Cairo	30 4 36	4,790	27·0	55	0	5·2	26·8	62	0	5·7	24·9	70	0	4·3	22·8	71	drops	4·5
2	Asyut . . .	27 11 0	4,430	28·7	..	0	12·5	29·3	40	0	12·9	27·5	46	0	9·4	24·6	56	0	6·9
3	Assuan . .	24 2 25	3,950	32·5	20	0	13·2	32·5	20	0	13·2	31·6	32	0	12·0	28·5	41	0	8·8
4	Wadi Halfa .	21 54 49	3,580	30·9	27	0	..	30·0	28	0	..	29·3	29	0	..	26·3	39	0	..
5	Berber . .	18 1 0	2,480	32·9	30	0	..	33·7	24	0	..	32·6	28	0	..	29·4	34	0	..
6	Khartum . .	15 38 20	2,130	30·1	47	116·4	..	31·2	46	5·3	..	30·0	41	1·8	.	..	..	..	..
6a	Omdurman .	15 38 20	2,130	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7	Wad Medani .	14 24 0	2,010	28·2	57	135·0	..	28·4	60	78·0	..	28·4	56	243·3	..	29·8	38	2·4	..
8	Duem . . .	14 0 0	1,970	28·1	59	126·6	..	28·2	61	69·4	..	28·0	61	59·8	..	29·0	36	6·2	..

NOTE.—The daily mean temperature is deduced from the formula $\frac{8h + 14h + 20h + m}{4}$ in the cases of Giza, Abbassia, Asyut in August, September and October, Assuan, Khartum, Omdurman in May and June; the other daily mean temperatures and all the relative humidities are deduced from the formula $\frac{8h + 20h}{2}$.

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Mr. Dyce Cay. as to expedite the passage of floods from the upper reaches of the White Nile, which would increase the flow in Egypt in the summer months, before the flood season of the Blue Nile and of the Atbara commenced.

Mr. Ford. Mr. J. T. FORD observed that there seemed to be a slight discrepancy between the statement (p. 98) that five times the amount of excavation provided for in the contract had been made, and that on p. 104 to the effect that the excess was 100 per cent. for the excavation and 45 per cent. for masonry. Inasmuch as the primary object of such Papers was to serve as means of comparing the work described with other great works, cost was an important point; and in this respect Mr. Fitzmaurice's Paper was somewhat vague. At p. 77 the contract was said to have been let for £1,500,000 for the dam, and £500,000 for the weir at Asyut. No further mention was made of the weir, hence, apparently, the total cost given at p. 104, £2,450,000, was for the dam alone. He would like to know whether the latter figure represented the actual cash payments to the contractor, and, if possible, to have an approximate statement of the extras paid for, both in quantities, classification and unit prices, with a statement of daily or piecework wages paid for different kinds of labour, skilled and unskilled. He would also be glad to know the extra cost to the Egyptian Government of engineering and supervision generally, as well as for the preliminary work of commissions, estimates, etc., so that some idea might be formed of the actual total cost, in view of the financial scheme mentioned on p. 77 for raising the money on 30-year bonds for £4,716,780. If such figures could be given they would add greatly to the completeness and utility of the Paper, both to engineers and contractors.

Mr. Marrian. Mr. A. E. MARRIAN remarked that he would be glad if Mr. Fitzmaurice could give any details as to the amount of work done per man per hour on the sudds, etc., as being an interesting and important consideration in such works executed abroad. In tipping earthen banks for railways in West Africa the natives mostly used baskets on their heads, and would not carry more than about ½ cubic foot at a time. Of course there such labour was very cheap. Referring to the rotten granite in the foundations, it would be interesting to know whether the material quarried for the dam was similar in composition to that of the bed of the river, and whether the deterioration of the latter was due to its composition—for instance, to abundance of felspar or to the presence of iron—or was rather accounted for by its extreme age. It was mentioned in the Paper that a little expenditure on borings would have disclosed

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the state of the bed; and as at low Nile about 80 per cent. of the bed of the river was dry, it appeared that trial holes at intervals should have given a good approximation to the amount of soft stuff to be excavated. Mr Marrian.

Mr. JAMES PRICE observed that he was interested in the Papers, as they described works similar in some points to those of which he had had charge on Lough Erne, Co. Fermanagh, in 1882–88.[1] The principal work at Lough Erne had been the cutting of Belleek falls and the erection of four Stoney free-roller sluices of 30 feet span at a level of 12 feet below the original crest of the falls. In order to dry the site for the sluices, rock banks had been formed in the stream above the crest, and when the force of the current had been broken, dams of clay in bags had been built behind the rock banks. The diagrams given in Mr. Fitzmaurice's Paper afforded interesting information. If the Author would show in diagram form the discharge of the Nile at different gauge-levels it would be useful in illustrating the discharge in large channels partly controlled by natural weirs. From Fig. 8, Plate 1, between the gauge-heights of 84·25 metres and 86 metres the discharges seemed to increase as the ordinates of a curve; between 86 metres and 90 metres the discharge was proportional to the height of gauge, and between 90 metres and 103 metres the discharge increased again as the ordinates of a curve—the whole, when plotted, giving a distorted hyperbolic curve. A similar diagram of discharge for different heights of Lough Erne with the channels in their natural state had given an approximately hyperbolic curve. The sluices erected at Belleek in 1883 had been the first Stoney sluices erected in the United Kingdom; and a comparison between the Belleek and the Assuan sluices might be of interest, as showing the completeness of the inventor's design 20 years ago. The following Table showed the respective dimensions:— Mr. Price.

Sluices.	Span.	Height.	Area.	Weight.	Pressure.	——
	Ft. Ins.	Ft. Ins.	Sq. Ft.	Tons.	Tons.	
Belleek . . .	29 2	14 6	427	13	100	Rollers.
Assuan, R.L. 87·5	6 6¾	23 0	152	13	210	,,
,, R.L. 92·0	6 6¾	23 0	152	9	150	Sliding.
,, R.L. 96·0	6 6¾	11 6	76	6	60	Rollers.
,, R.L. 100·0	6 6¾	11 6	76	5	30	,,

In details the Assuan sluices were similar to those at Belleek in

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 73.

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Mr. Price. form of rollers, stanching-bars, rocking beam to take roller-pressures, and dimensions of sluice-grooves. The grooves for the Belleek sluices were in the masonry of the piers, with the castings bolted to the masonry. The difficulty of getting the masons to work to exact dimensions had suggested to Mr. Stoney the construction of the grooves in cast iron, and building the masonry round them, as had been done at Assuan. The side walls at Belleek were of limestone set in cement; and the inverts, some limestone in cement and others concrete. The scour from the sluices cut out both forms of invert, though the velocity was not more than 28 feet per second. The cast-iron inverts and linings at Assuan were therefore a necessary improvement. At Belleek the lifting was done by screws at each side of the gates, connecting the gate-rods to the nuts. Under the horizontal gear-wheel on the screw-head, to bear the weight, was a ring of coned rollers, each alternate roller being turned smaller, so as to act as a distance-piece between the other rollers, and thus do away with all sliding friction. The gearing was arranged so that each pair of screws worked together, and was actuated by hand or by a small turbine. In practice it was found that a boy could work any of the Belleek sluices, and there was no perceptible difference when the full pressure or no pressure was on the gates. When the winch-handles were slipped out of gear, the gates, if started, would descend slowly, their weight being just sufficient to overcome the friction of the gear, screw and rollers. This method of lowering was always used until there was sufficient head of water to keep the turbine moving. The great height of dam above the sluice no doubt necessitated the use of wire-ropes for lifting at Assuan, and if the winch-handles could be slipped out of gear the sluices would probably run down of their own weight. The use of sliding sluices at R.L. 92 was somewhat surprising; unforeseen circumstances might arise, requiring that these sluices should be worked under a full head; and then the results might be disappointing. It was not quite clear why such small sluices should be used at Assuan: the resistance to motion arising from water-pressure in roller sluices was so small that it might be neglected; and if the sluices had been doubled in width, the moving weight of each would not have been more than that of a Belleek sluice. The number of sluices might then have been reduced to eighty, which would have led to considerable saving in gearing, sluice-grooves, rollers and culvert-lining; or the top row of sluices might have been made 20 feet wide.

Mr. Siccama. Mr. H. SICCAMA remarked that the Assuan dam worthily inaugurated the series of wonders of the world which would probably

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be added to those of old during the twentieth century, as the Forth Bridge had closed the series of the nineteenth century. Though the mass of the structure and its money cost might perhaps be exceeded in other works, it was the energy, thought, and resourcefulness expended on it which would mark this successfully-completed task as a great triumph. Only those who had had to work under similar conditions of distance from the base of supply, quality of local labour, and climate, could appreciate at its full value the grit and courage of the responsible builders. He supposed that, although the rock found in the river-bed was to a large extent untrustworthy for foundations, it was hard enough to permit the omission of an apron on the down-stream side of the dam. Also, the absence of a side weir or safety overflow might have some excellent reason, but it seemed to him that in a region so far removed from civilisation there might at some time or other be the coincidence of an extraordinary flood and the want of proper supervision, so that the flood-level might overtop the dam. In such an event, would there be any danger to the structure? It would also be instructive if the cost of the work, apart from incidental expenses, could be given, or unit prices for excavation and masonry. Some idea as to the cost of housing and feeding the working force would interest him; and he would like to know whether it had been possible to cover some of these charges from the wages paid. Engineers had so often to execute work departmentally in the desert places of the earth, that the experience gained here might be useful on similar occasions. Mr. Siccama.

He was much interested in the ingenuity displayed in solving the many problems presented by the sluices. He would like to know how the pressure from the turbine in the dam was conveyed to the accumulator-house east of the locks: whether the pipes were carried underneath the lock-bottoms, or whether they must be disconnected each time vessels passed through the locks. Further, he thought a swing-bridge would have been a simpler device than the drawbridge shown in the drawings. No doubt a good reason had existed for adopting a segmental horizontal section for the lock-gates, but would not a rectangular section have been more easily balanced for rolling into recesses? He also inferred that valves in the gates were preferred to culverts in the lock-walls, for fear of such culverts or submerged passages silting up; but if there were any other reason for adopting this construction, it would be interesting if Mr. Stokes would state it.

Mr. Lionel B. Wells remarked that information as to the area of land brought under cultivation, and the area to which a full Mr. Wells.

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Mr. Wells. supply of water would now be given where formerly only a partial supply had been available, would be instructive; indeed, a Paper dealing fully with the irrigation work, and its effect on the soil, population and revenue of Egypt, would be a valuable contribution to the "Proceedings," for the importance of these subsidiary works was second only to the great work of dam-construction. The reason for building in rubble masonry instead of concrete was not stated. It was useful to note the fact that cement made in England had proved to be better suited for this work than material found on the ground. It showed plainly the advantage of having an industry organized. He had frequently found sand useful in making temporary dams, using it in a loose state, however, with a view to its being either washed away or removed by dredging. He had constructed a dam of this kind in the main navigation of the River Weaver. The channel was 85 to 90 feet wide at the surface, 30 feet at the bottom, and 11 to 12 feet deep. Sand had been dredged for maintenance and deposited by hoppers to form the bottom of the mound, leaving a navigable depth of 9 feet 6 inches. Sand had also been dredged into lighters and wheeled on to the banks, to form a reserve for replenishing the mound during the stoppage. Traffic having then been suspended, the dam had been raised by emptying hoppers as long as the water remained deep enough, and afterwards by discharging from lighters. The mound had been quickly completed, and easily maintained against the full pond above, during the stoppage, which had lasted for a fortnight. It had then been reduced by loading the sand into lighters, and when the mound had become no longer trustworthy, the water had been allowed to rush through. A dredger had then been set to work upon the wreck of the dam, and had made in a short time a navigable passage, which had been enlarged at leisure. The dam had proved efficient; it had been quickly made and quickly removed; and the whole cost had been small. The advisability of enlarging the entrance to sluice-culverts could be seen readily where the openings were above water. From Fig. 11, Plate 4, it appeared that little rounding was given to the sill of the culverts through the dam, and there was nothing to show whether the sides followed the lines of the top or of the sill. The Dutton sluices,[1] which he had completed in 1881, were eight in number, and were worked by a single crab which travelled overhead from sluice to sluice. The arrangement

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 114.

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generally had been most satisfactory. Up to 1888, when he had ceased to have charge of the River Weaver, no difficulty had arisen in working the sluices, nor had they suffered from floating débris. The sluices and other improvements carried out on the Weaver had had so marked an effect on the discharge of floods that whereas 25 years ago there had been floods of 7 feet and 8 feet, a rise of 2 feet on the navigation-gauge was now commented upon as a high flood-level. The absence of a longitudinal section of the canal and locks was a drawback, and the small scale adopted for the drawings generally rendered it difficult to follow the details. He feared that mud would be deposited in the locks in troublesome quantities, and that side culverts would be found necessary, not only for assisting to clear away mud, but also for distributing the influx of water, and thus lessening the risk of vessels being knocked about in the process of locking. Mr. Wells.

Mr. FITZMAURICE, in reply, observed that he was unable to give the origin of the datum used at Assuan. All levels were referred to the datum in use by the Irrigation Department all over Egypt, which certainly varied little, if at all, from the mean level of the Mediterranean. The too-rapid setting of the cement mortar used had been prevented by keeping all masonry damp for 10 days after building. Referring to Sir R. H. Brown's remarks, he regretted that anything in the Paper tended to encourage the delusion that the Assuan dam would in any way affect the discharge of the Nile while the river was in flood. What he intended to convey was, that a large amount of land now irrigated solely by flood-water would, in the future, be under perennial irrigation; and therefore, in the case of a bad flood, there would not be so much flood-irrigated land to cause anxiety as in the past. He was unable to give the gradient of the water-surface in the full reservoir. This information had not yet been obtained, as the reservoir had only just been filled for the first time. With regard to Mr. Dyce Cay's observations, he did not think that the average evaporation shown by the Egyptian Government Meteorological Reports could be applied to the Nile. The result of measurements on a very small scale did not appear to be applicable to a river of considerable depth and volume. In his book on Egyptian irrigation, Sir William Willcocks, who had studied the subject carefully, gave 7 millimetres per day as the summer evaporation of Upper Egypt. Mr. Dyce Cay's figure for the average width of the Nile in summer, between Assuan and Asyut, was about three times too large. In reply to Mr. Ford, it was stated in the Paper that, during the season of Mr. Fitzmaurice.

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Mr. Fitzmaurice.

1900, five times the amount of excavation provided for in the contract had been taken out. Taking the whole length of the dam the amount of excavation had been 100 per cent. in excess of the contract quantities. Both statements in the Paper were correct. The £2,450,000 represented the total cost of the Assuan dam alone, and was the actual cash payment to the contractors. The extras paid had been almost entirely on account of the additional excavation and masonry, necessitated by finding unexpectedly large depths of rotten rock. In answer to Mr. Marrian, where loose sand or earth had been tipped on to sudds it had generally been carried in baskets on the heads of natives. The greater part of the sudds, however, had been made of sand in bags, or of rock, which had been brought on to the sudds in trucks, or by boat. The granite quarried for masonry had been absolutely solid, but of course it had had to be chosen carefully. It had been obtained largely from big boulders, many of which contained 50 to 200 cubic metres. With reference to the composition of the rotten granite he could add nothing to the information given in the Paper. The following Table would give Mr. Price the information he wished for, as to the discharge of the

Assuan Gauge in Metres.	Approximate Corresponding Discharge in Cubic Metres per Second.	Assuan Gauge in Metres.	Approximate Corresponding Discharge in Cubic Metres per Second.
85·00	410	90·00	4,350
85·50	610	90·50	5,100
86·00	830	91·00	5,850
86·50	1,080	91·50	6,600
87·00	1,390	92·00	7,600
87·50	1,720	92·50	8,600
88·00	2,130	93·00	9,800
88·50	2,600	93·50	11,200
89·00	3,100	94·00	12,800
89·50	3,600	..	..

Nile at different gauge-levels. There were many reasons why it was not advisable to have the sluices, particularly the deeper ones, larger than those adopted at Assuan. With a number of small sluices the discharge was delivered at numerous points instead of being concentrated at a few places. This was in accordance with the advice of the International Commission, referred to in the Paper. The distribution of the stresses in the masonry was better dealt with in this way, and there was less chance of cutting out rock down-stream of the dam. It was necessary, as far as possible, to send water down two channels at all times, as there were

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villages on both channels just below the dam, and as in March and April very little sluiceway was required, it was necessary to have the small amount of water going down well distributed. With larger sluices, the gates, which were unbalanced, would have been much heavier and more difficult to manage. There would also have been difficulty with the sills and lintels of larger sluices. It must be remembered that one hundred and fifty out of the one hundred and eighty sluices were lined with granite, not with cast iron. If larger sluices had been adopted, with masonry lining, the inverts and sills would have had to be arched: this would have taken longer time, which, in view of the shortness of the season for working, would have been a serious matter. Of course, cast iron could have been adopted in larger sluices, but it would have been more expensive. Probably the most satisfactory plan for larger sluices would be to build the side walls in granite ashlar, and to use cast iron for the sills and lintels. In the event of a mishap to one or two of the existing sluices, it would not seriously interfere with the working of the dam if they were closed for a season; while with large sluices this course might be very difficult. The arrangement devised for shutting off a sluice by means of a shield was quite complicated enough for the Assuan sluices, and would have presented great difficulties with any sluices of much larger size. Should a boulder or a large piece of timber prevent one of the deep sluices from being fully closed when the reservoir was being filled, it would be a very serious matter if the sluice could not be shut off by means of a shield or otherwise. When the reservoir was full the water would flow through the sluice under a head of about 18 metres, and with a velocity of about 18 metres per second. With this velocity the lining of the sluices and the granite down-stream of the dam might be affected. He quite agreed with Mr. Price that the resistance arising from water-pressure in free-roller sluices was so small that it might almost be neglected; but this had not been the determining factor in settling the size of the Assuan sluices. The velocity of 28 feet per second at Belleek was very high, and it was not surprising that the limestone and concrete were cut out. In reply to Mr. Siccama, it would probably be necessary to lay a masonry apron below the high-level sluices on the high ground, where there was no water-cushion, in order to lessen the effect on the rock of the discharge from these sluices at low Nile. He thought that, with the large number of sluices, and the practical certainty

Mr. Fitz-maurice.

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Mr. Fitzmaurice. that at the most only three or four could be out of order at one time, there was not the least necessity for a spill channel. Even in a most exceptional flood of 14,000 cubic metres per second, the water on the up-stream side would not rise within 3 metres of the full-reservoir level. Of course while the reservoir was filling—at which time the discharge of the Nile was small in comparison with the flood-discharge—the level of the water was absolutely under control. He could not conceive any conditions under which the water would top the dam; but should such an event ever happen, any damage done would not extend beyond the parapet. With reference to the absence of culverts in the lock-walls, and to depending on the sluices in the gates, he considered that the working of the locks would be much simplified if culverts had been used, and he would wish to adopt them in any similar work. The principal reason why they had not been used was, that it had been anticipated that solid granite would be met with in the locks, and that masonry facing to the granite would be all that was necessary for the side walls: had that been so, culverts would have necessitated tunnelling through the granite.

Mr. Stokes. Mr. STOKES, in reply, remarked that it was difficult to draw any close analogy between the Belleek sluices and those at Assuan, because at Belleek the larger dimension was horizontal, while at Assuan it was vertical. Also, at Assuan there was a considerable head of water above the sluices, while at Belleek the water never flowed over the top of them. With regard to the sluices at R.L. 92 without rollers, it was difficult to imagine circumstances which would require these to be worked with a full head against them, because the sluices at the same level with rollers, and those at R.L. 87·5, provided more than ample area for discharge. The 25-ton steam-crane could, however, if necessary, assist the lifting-gear of these sluices, so as to open them against a considerable head. In reply to Mr. Siccama, the water from the turbine pumps was taken across to the west of the locks by duplicate copper pipes carried across the bottom of two gate-recesses, the necessary stop-cocks being provided to cut off either pipe should it become damaged. With regard to the lift-bridge, this class of bridge was most common in Egypt, and had some advantages over a swing-bridge, notably the absence of any pit into which people might fall. The bridge was also quickly and easily operated, and there was nothing to get out of order. The principal objection to culverts in the lock-walls in the case of the Assuan locks as originally designed

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was that, owing to the head, a considerable pressure would have had to be provided for, which would not have been practicable, as good rock had been anticipated, and this was to have been only faced with dressed masonry. In carrying out the work, however, bad rock had been met with which had rendered necessary the section of wall shown in the illustrations. No doubt, had this been known in the first instance, culverts would have been adopted as suggested by Mr. Siocama. The enlarged entrances to the culverts were apparently ample, because with the water in the reservoir just level with the top of the culvert entrance, the culvert ran full bore on the down-stream face of the dam, which was a satisfactory result. With regard to mud in the locks it had been found that after one season's working and flood, there was remarkably little deposit, and no trouble whatever had resulted from it. With the present arrangement of sluices in the lock-gates, the locks could be filled with little disturbance to the water, much less in fact than with side culverts. This was doubtless due to the sluices being distributed over the lock-gate, and also to the long sluice at the bottom of the gate, the discharge from which tended to counteract any back-water action, which might have been a trouble. Vessels could be locked without any risk of their being knocked about. Mr. Stokes.

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3 February, 1903.

JOHN CLARKE HAWKSHAW, M.A., President, in the Chair.

The PRESIDENT mentioned that the Institution had lost one of its most distinguished Honorary Members, Sir George Gabriel Stokes, Bart. Endowed with the highest mathematical ability, Sir George Stokes, like Sir Isaac Newton, had devoted his life to scientific research at Cambridge, and, like Sir Isaac Newton, he had been President of the Royal Society and had represented his University in Parliament. All civilized nations would feel his loss, as all would benefit by his life's work. At a meeting of the Council held that evening the following resolution had been passed, in which he was sure all present would concur: "That the Council deeply regret the death of Sir George Gabriel Stokes, a distinguished Honorary Member of the Institution, and desire to convey to Lady Stokes an expression of sympathy in her bereavement."

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It was announced that the Associate Members hereunder mentioned had been transferred to the class of

Members.

JOSEPH WILLIAM BROWN.
ROBERT BUSH, B.A. (*Oxon.*)
WILLIAM MORRIS GALE.
GEORGE DAY HARRISON.
HENRY WEDGWOOD RENDEL.

And that the following Candidates had been admitted as

Students.

HILARY REGINALD ANDOE.
SYDNEY BOWEN.
CHARLES JOHN EVAN DAVID, B.A. (*Oxon.*)
WALTER ERNEST FOX, B.E. (*Royal.*)
PERCY CHARLES KINGSBURY.
HAROLD MCCOMAS, B.A.I. (*Dublin.*)
HARRY EVELYN MARSH.
ERNEST GEORGE DEWAR MATHEWS.
OWEN FOSTRIC PARKER, B.A. (*Cantab.*)
VERNON CHARLES SMITH.
FREDERICK ROBERT STEWART, B.Sc. (*Glas.*)
ARTHUR TREWBY, B.A. (*Cantab.*)
HAROLD CRAIGIE WILLIAMS, B.A. (*Oxon.*)

The Candidates balloted for and duly elected were: as

Members.

WILLIAM JOSHUA HARDING.
EDMUND DU CANE SMITHE.
JOSEPH WILLIAM WILLMOT.

Associate Members.

GEORGE ERNEST ASHFORTH, M.Sc. (*Victoria*), Stud. Inst. C.E.
EDWARD ALEXANDER MORGAN BINDLOSS.
BENJAMIN CHAPMAN BROWNE, Junr.
JOHN MARTIN CLARK, Stud. Inst. C.E.
RALPH SMITH OLIVER CUSACK.
CUTHBERT BARING HORWOOD.
MARCUS MERWAN RUTTONJEE KHAREGAT.
MALCOLM LITTLE, Stud. Inst. C.E.
NICHOLAS MAUGHAN.
JAMES DAVIS PEARSON, B.A., B.E. (*Royal.*)
HUGH WYATT STANDEN.
FREDERICK OWEN STANFORD.
CHARLES FRANCIS RUSSELL NUGENT WESTON, Stud. Inst. C.E.
DAVID WILSON, B.E. (*Royal.*)
JOHN SIGISMUND WILSON.
DOUGLAS HALLIBURTON WINDSOR, Stud. Inst. C.E.

The Discussion upon the Papers by Messrs. Fitzmaurice and Stokes on the Nile Reservoir and Sluices, Assuan, occupied the evening.

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SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 3340.*)

"The Construction of the Lu-Pao District of the Lu-Han Railway."

By THOMAS JOHNSTONE BOURNE, Assoc. M. Inst. C.E.

IN the year 1896 a Chinese Imperial edict sanctioned the more extended pursuance of a policy of railway construction, with special reference to the immediate construction of a trunk line from Peking to Hankow on the Yangtsü River, His Excellency Shêng Hung Shuen being appointed Director General of Railways. The Tientsin-Peking Railway having already been partly constructed, between Peking and Lu Kou Chiao, the line was designated by the conjunction of the first syllables of the names of that place and of Hankow, being called the "Lu-Han" Railway. During the recent troubles the French engineers under Mr. Bouillard pushed the line up to the Chien Mên (Gate) at Peking, and the line is now known as the "Pei-Han" Railway.

The funds for such an enterprise could only be secured from abroad, by granting a concession for the construction of the line by some foreign syndicate. The Chinese being unwilling to grant such a concession as would give reasonable security, freedom of action and authority to concessionaries, it seemed unlikely that capital would be forthcoming, and in this juncture the Chinese Director General of Railways, pressed by the Imperial Government to commence work, requested Mr. C. W. Kinder, C.M.G., M. Inst. C.E., the British Engineer-in-Chief of the Imperial Chinese Railways, to construct the first natural division of the line, namely, that between Lu Kou Chiao and the prefectural City of Pao Ting Fu (and hence called the "Lu-Pao" Railway), for the Chinese Government. The work was therefore undertaken as a part of the established system of Chinese Northern Railways, and the Author was appointed Resident Engineer for the work, under the Engineer-in-Chief, and remained in charge of the district from the preliminary survey to the final completion of the line.

The total length of the projected Lu-Han Railway is about 600 miles, and the length of the Lu-Pao district from Lu Kou Chiao

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to Pao Ting Fu is 80 miles, with a 10-mile branch. The gauge is 4 feet 8½ inches.

It is scarcely necessary to detail the objects or advantages of such a railway. China being a fully settled country, in which practically all the land which can be worked with any prospect of a bare living is utilized to the full, and with an ample and industrious population possessing keen trading instincts, it is evident that good communication is a necessity. Nor is it necessary to teach the Chinese to use modern means of transport. The present transport system is so bad, and at the same time the traffic is so great, that the possibilities of a railway for cheaper, safer, and quicker communication and transport are at once seized upon. Chinese waterways, left to nature as they are, constitute the only existing means of really cheap transport for heavy and bulky commodities over long distances, and these have not been, and the Chinese are unlikely to allow them to be, curtailed in usefulness by any railway monopoly. The water-carriage to Peking, however, from any part of the country traversed by the Lu-Han line, is very circuitous, and stops 10 miles from the Capital on one river and 30 miles from it on the other. The Lu-Han Railway being connected with Peking, the capital city of the empire, as well as one of the largest in population, and also with Tientsin, the great entrepôt of the north, by the existing Northern Railways, a fair traffic was at once insured. This was largely increased by the construction of a 10-mile branch from Liu Li Ho, 30 miles from Peking, to the nearest point affording a convenient centre for the native anthracite mines which from time immemorial have sent coal by pack animals—camels and mules—to Peking. This coal is sent in the same way to the head of the navigation of the Liu Li River, whence it is taken by water both to Tientsin and to the whole area served by the network of water-ways shown on the accompanying map, *Fig. 1.* Lime also, which is used in great quantities all over Northern China, has for centuries been burnt in the same place, and this took the same routes as the coal. To afford some idea of the relief given to transport from this one centre only, it may be mentioned that one car-load of coal has been estimated to take the place of a continuous line of laden camels, with their drivers, about ½ mile in length.

The main line from Lu Kou Chiao to Pao Ting Fu traverses a rich grain country, most of which gives three crops a year, wheat, millet and beans, and in good years there is a considerable excess available for Peking. This is brought to the railway by carts and pack animals from the north-west or hilly side of the line, and

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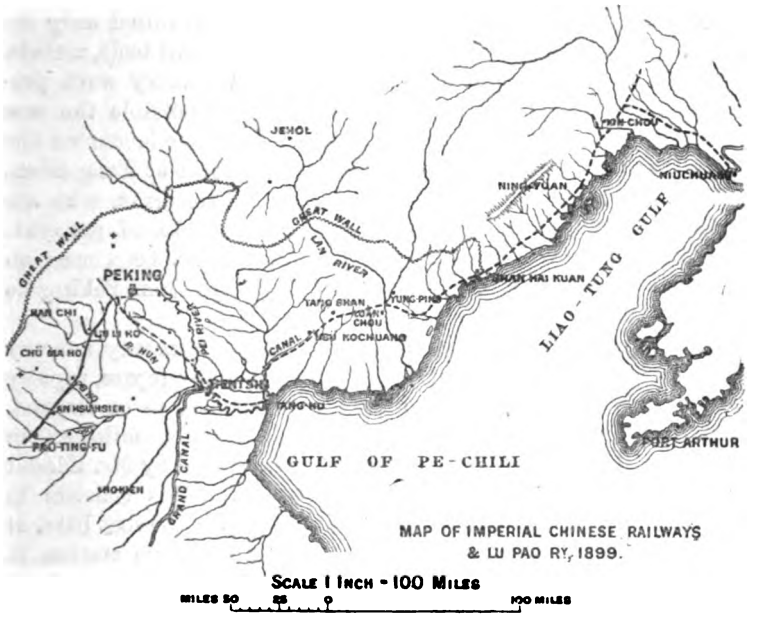
by boat from the alluvial plains to the south-east. The line crosses a series of rivers, of which two, the Liu Li Ho and Pao Ting Fu, are navigable, except during the winter season, up to the points where the line crosses them. For three months in the winter the lower portions of these rivers are closed by ice, and navigation is suspended along their whole course. Several of the other rivers also are navigable during part of the year, and serve as feeders and distributors for the line, which may now be expected to share in the benefits of the trade which these rivers

Fig. 1.



have for centuries fostered. The boats trading to the heads of these rivers, where the line crosses them, are generally of about 5 tons to 20 tons burden and about 2 feet draught.

General Character of the Country.—With the exception of the first 2 miles, where the line skirts the base of the hills of the western range, the railway is through an open, level country, on the fringe of the Loess formation, and, except for some wide valleys, is well raised above the low and frequently inundated plain lying to the east of it. The whole tract is covered with villages 1 mile to 2 miles apart, each consisting of some fifty to a

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hundred families. There are also walled cities at intervals of about 10 miles along the route. Lying at the base of the hills (Hsi Shan) at its northern end, and about 30 miles from them at Pao Ting Fu, its southern end, it crosses all the lines of watershed, and the drainage of all the country to the west of it has to pass under the line. Building material, cut stone, rubble, broken stone for concrete, sand and lime, as well as gravel for track ballast, were procured from the quarries at the end of the branch line. Timber is procurable locally in small quantities only, and is of poor quality and small dimensions. Soft native brick, suitable only for walling to houses, may be obtained near each town or large village. The lime is non-hydraulic and is suited only for mortar for walls of buildings and similar work. All tools, metals, Portland cement, and general stores and machinery were procured from Europe and America, but wherever possible the raw products were imported and manufactured by native labour on the spot. Within the last two years the cement-works at Tang Shan, near the collieries, have been re-started by Germans, who are making five thousand casks per month at about 7*s.* 6*d.* per cask. This cement is said to be of fair quality, and has been used on the recent extension of the Northern Railways from Peking to Tung Chou.

Preliminary Survey.—China having no Ordnance survey, nor any map suited for engineering work, it is necessary to prepare, rapidly and cheaply, a route survey of the line of country to be covered, from which to obtain the general direction to be followed in location. The method adopted has been described by Mr. Kinder in a Paper[1] presented to the Institution. This consists in measuring the angle subtended at station A by a 100-foot base, at right angles to the line of sight, measured out from station B. The length of each line of the traverse can then be read off directly from a table of cotangents, by moving the decimal point two places. From each station cross-bearings are taken on all objects of any importance, and on all serious obstructions to a possible location, such as villages, groups of graves, etc. The instrument used was a 4-inch Troughton theodolite with trough needle. The needle, being 4¼ inches in length, gives very accurate bearings, and, owing to the sides of the trough limiting its oscillations within a small arc, it is quickly steadied. The lower plate being set in the magnetic meridian, all bearings

[1] "Railways and Collieries of North China," by C. W. Kinder, M. Inst. C.E. —Minutes of Proceedings Inst. C.E, vol. ciii. p. 278.

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could be taken very rapidly by turning the upper plate only, without the disturbance of the needle which occurs in a prismatic compass. The traverse thus made was plotted daily by meridians and perpendiculars, this work being done by a Chinese engineering student, and two survey books being used, that of the previous day always remaining behind with the draughtsman. The plan was thus completed daily a few hours after the field-work. The variation of the compass used, along the route, was found by two separate observations of Polaris to be 2° 31′ westerly. The preliminary survey of 80 miles by this method was commenced on 20 December and completed on 28 December, 1896, the working time having been $7\frac{3}{4}$ days, and the best day's run 14·2 miles. This survey was found to check almost perfectly with the final location survey. The party consisted of the Engineer-in-Chief, assisted by the Author, with one Chinese student, one interpreter, and six survey coolies carrying flags and instruments. A light cart was taken into the field for carrying out poles, pegs, etc., and for giving the coolies a lift to and from their work.

Location.—The country passed through is very easy, and some pains were taken to obtain the straightest line possible. With the exception of the first four, all the curves on the main line were of 8,000 feet radius, and the whole 80 miles was got in with twenty-five curves, the longest straight being 9 miles and the sharpest curve 2,000 feet radius. The maximum gradient is 1 in 300, and is nearly all at one end of the line. The general location was fixed by the towns and trading centres on the route, the rule being to keep so far from the towns as to be sure of ample land at a cheap rate, and to avoid fouling the fringe of graves, houses, gardens, etc., round towns and villages. The locating party consisted of the Author and one European assistant, with three Chinese students and a number of coolies. One of these students set out the stakes to the intersection-poles at an average rate of 3 miles per day, the stakes being 200 feet apart on tangents and 100 feet apart on curves. Another student followed with a compass survey of the country, taking cross-bearings and tape-measurements from the stakes. The location survey being carried out in midwinter, the ground was frozen hard to a depth of several feet, and a heavy steel drift driven with two sledge-hammers had to be used for each peg placed and also for ranging-poles. Great difficulty was experienced owing to the pegs rebounding out of their holes even under the blows of the heaviest hammer. Finally the pegs were shortened and cut to the triangular shape of the drift so as to fit the hole exactly and make a driving fit in the

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solid ground. The whole route was covered with 2 inches to 3 inches of snow during location. A 5-inch Troughton theodolite was used for ranging the line and fixing the intersections, and pegs were centred with a 4-inch theodolite by the same makers. Stadia-hairs fitted to the 5-inch instrument were found convenient for roughly estimating distances and fixing the approximate position on the plan of the preliminary survey.

A considerable number of graves were cut by the line, which was not diverted for each grave or small group of graves, it being left to the Chinese officials of the line to suggest such deviations, if necessary, to prevent trouble. The major graves and larger groups having been avoided, no protest was made in any case, a fixed sum being paid to each family for moving and re-interment, and all the land being paid for directly the half-widths were marked out. Some few graves were cut which had passed out of memory, and in one case a group proved to be the criminal burial-ground of Pao Ting Fu, having, therefore, no sacred associations or market value.

When the first 10 miles had been staked and levelled, and the section plotted and approved, the half-widths were sent back to the Chinese party of land-buyers, headed by an official of some rank, who immediately followed and bought the land as quickly as location and plotting could proceed. Exception to this procedure was made only in the case of two householders whose huts were included in the land required and who proved recalcitrant for a month or two. Some trouble was occasioned near one or two rowdy villages by the removal of intersections and flags, and a large number of pegs were taken up between the putting-in of centres and the taking of levels, and had to be replaced, notwithstanding that the village headmen were subsidized by the officials, under a penalty, to watch the pegs. During construction, when the pegs were put in for making up and trimming banks and cuttings, a "peg watchman" had to be engaged for every mile of line to see that these were not removed. The location was commenced, with one engineer and one Chinese student, about the 1st January, 1897, and on the 12th January the whole party were at work. On the 25th January the first lists were given to the land-buyers. On the 16th February all intersections were in, and on the 1st March the levels over the pegs were completed. By the 17th March all plans and sections were completed and traced, halts being made from time to time at the inns or temples which constituted the party's quarters for this purpose.

Earthwork.—The Chinese directorate elected to carry out the

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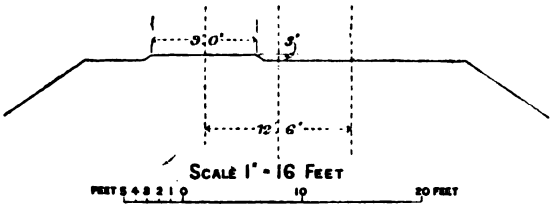
earthworks themselves—work which the Chinese, through practice from time immemorial, are well able to undertake—and as, with the exception of one rock-cutting, the whole of the work was done by shovel and basket from side-cuttings and heaps, they were furnished with a list of the heights and depths, ample allowance being made for settlement, and the work was started in the last week of April, 1897. About 50 miles was taken up and reported as finished by the officials concerned before the rains in July, but, as usual, although on the whole the work was fairly well done, the full heights and depths were not observed. The work had therefore to be trimmed and made up in the following autumn, and, in spite of protest, the same official was allowed to make good his work. Again, however, level-pegs were found to have been driven down on the higher banks; and, finally, in the spring of 1898, the engineers had to complete the work to true level, width and slope, with their own petty contractors. By this time some 20 miles of rails had been laid, so that, in order to secure true

Fig. 2.



gradients and to save ballast, the track had to be packed up in places by flying gangs, with earth supplied by the contractors. In advance of the rails a strip 9 feet in width, on which to lay the sleepers, was raised 3 inches above the rest of the formation (which itself had a special allowance for settlement when filled), as shown in *Fig. 2*. The width of bank was 32 feet, and the slopes were all $1\frac{1}{2}$ to 1. Cuttings were 37 feet in width at the intersection of the slopes with the formation, allowing a fair-sized open drain at the sides. The average price of the main bulk of this earthwork was about 1·1*d.* per cubic yard. For making up, a sliding-scale was arranged to allow for height of bank and length of lead, the lowest price paid being about $\frac{3}{4}d.$ per cubic yard.

The rock-cutting was let to separate sub-contractors. In this case drill-steel and other tools and gunpowder were supplied to the contractors at fixed rates. The cutting was through a very hard and tough rock, having the appearance of a metamorphosed

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limestone with clay in fissures. The excavation was small, and the whole of the material was used for concrete ballast and rubble for pitching and protection of bridges. The execution of ordinary earthwork in soft soil in China gives little trouble beyond measuring and levelling up. A native contractor will take up 40 to 80 miles of line, and will supply all his own men, tools, huts, commissariat, etc. No track, locomotives or plant are or can be economically used at the existing prices of land and labour. The "gulching" of the slopes of the banks was very severe during the rains, before the ballast was laid, and, on the east side of the formation, where there was no track, even after the line was fully ballasted. A growth very soon forms, however, and the cost of turfing would have been prohibitive. Grass and tree seed was sown in places, but the best protection was afforded by the equalizing and distributing effect of ballast, which prevented concentrated runs of water down the slopes.

Branch line for supplies of Rubble, Broken Stone, and Track Ballast.—The small rock-cutting mentioned being wholly insufficient even to supply concrete ballast for bridge masonry, and there being no other stone within reasonable distance of the line, or gravel for track ballast, it was necessary to arrange for these elsewhere, and it was found that at 10 miles from Liu Li Ho an excellent quarry could be established, providing fair rubble and good concrete ballast of limestone. Such dressed ashlar blocks as were needed could also be cheaply procured near by; lime was burnt at the same place, and the bed of a stream near the hills provided ample track ballast. It was therefore decided to lay a temporary line to this point to provide for the construction of the permanent line, but before the final location was begun the directorate decided that a permanent single-line branch should be built, as the head of this line would serve as a centre for the native coal-mines already mentioned.

On the 10th September, 1897, a preliminary contract was made for the supply of rubble and broken stone ballast from the quarry; and a fortnight later the preliminary survey was made. Location was completed on the 26th October, when about 2,000 cubic yards of rubble and ballast was ready. Earthwork for this branch was finished about the middle of December, being carried round bridge sites on diversions, and rails were laid during the following March and April. Notwithstanding that the banks were run over within 4 months of their completion, and before any rain had fallen on them, construction traffic was maintained continuously, with the exception of about 10 days spent in repairing washouts after a

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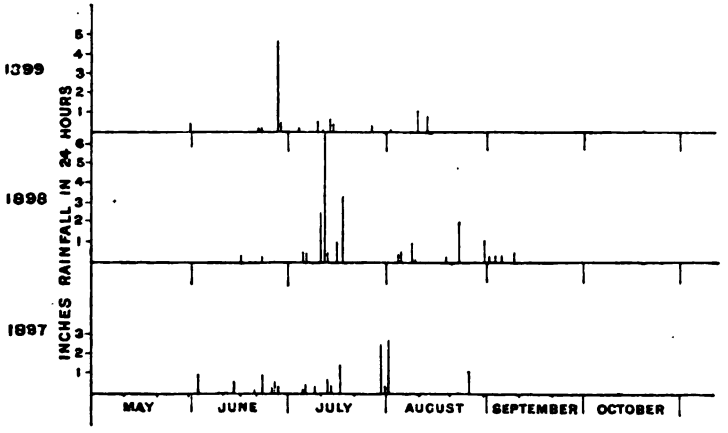
heavy fall of rain. The price paid for loading gravel into cars was about 1*d.* per cubic yard. The provisional price for rubble was about 9*d.* per cubic yard loaded into wagons, and 1*s.* 6*d.* per cubic yard for broken stone for concrete, but these prices were afterwards reduced to 6*d.* and 1*s.* 3*d.* per cubic yard.

Bridges and Flood-openings.—The total waterway found necessary was about 8,000 feet run of opening for the main line, or, on an average, 100 feet per mile. The rainfall at Liu Li Ho for the years 1897, 1898 and 1899, all of which were dry years, is shown in *Fig. 3.* Although the total falls for these years are so small, and the individual falls so moderate comparatively, the watershed probably extends 100 miles or more to the west of the line in the range of mountains known as the Hsi Shan, and the local records provide little indication of the fall over the whole catchment-area.

Fig. 8.



This is shown by the records at the various offices along the line for the 13th July, 1898, which were :—Liu Li Ho, 6·5 inches; Han Chi, 7·4 inches; Cho Cho, 5·25 inches; Pei Ho Tien, 4 inches; and An Hsi Hsien, 6·2 inches. Han Chi, at the base of the foothills, shows nearly 1 inch more than Liu Li Ho, which is 8 miles farther from the hills. The run-off is very rapid, owing to the proximity of the hills, the treeless and pastureless nature of the country, and the impenetrable nature of the top crust of the land. The floods on the low ground and in the valleys are very severe, as the rivers are wholly unable to take the run-off. At Liu Li Ho the river, during autumn, winter and spring, is about 60 feet in width, but in a heavy rain it rises 20 feet, and fills a valley nearly a mile in

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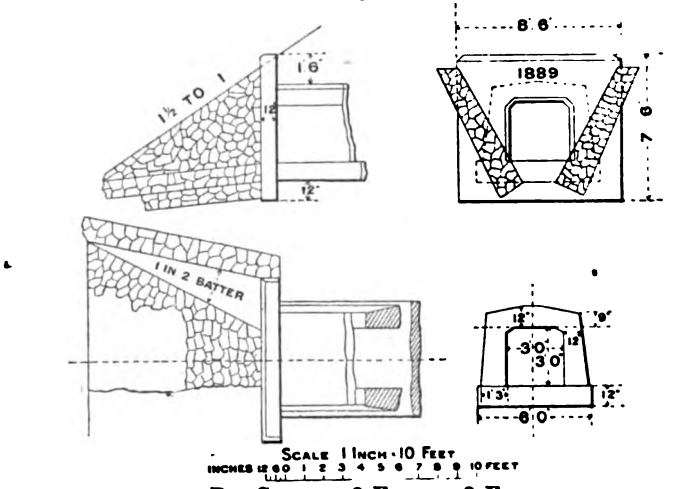
width, much of this water of course travelling at low velocity. The bridge provided here consists of twelve spans, each of 60 feet clear opening. At Chü Ma Ho the river meanders over a sandy bed, and has a width of about 100 feet in winter. In a heavy rain it rises some 12 feet, and fills a valley about 2 miles across. In this valley are provided two bridges, a flood-opening and a road bridge, giving in all 1,332 feet run of flood-way.

The chief major bridges are the following :—Liu Li Ho, twelve spans of 60 feet each; Chü Ma Ho, fifteen spans of 60 feet each; Pei Ho, eleven spans of 60 feet each, and eighteen spans of 30 feet each.

Consistently with local requirements the standards of the

Figs. 4.



BOX-CULVERT, 3 FEET BY 3 FEET.

Imperial Chinese Railways were strictly adhered to, and the openings adopted were all comprised within the following standards :—

Box-culvert, (*Figs. 4*)	3 feet by 3 feet.
„ „	4 „ 4 „
Arched culvert and cattle creep	6 feet span.
Arch for carts and water	10 „ „
Deck girder-bridges	12 „ „
	20 „ „
	30 „ „
	60 „ „

The box-culverts were entirely of concrete, and square in internal cross-section, *Figs. 4*. The quantity of concrete used in the 3-foot

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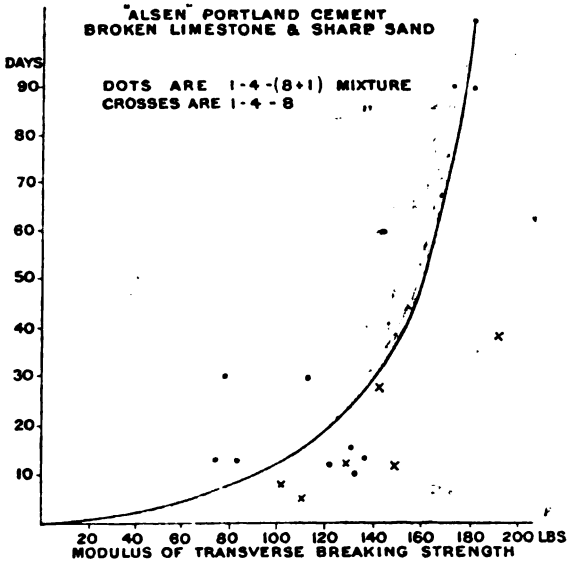
culvert was 17·33 cubic feet per foot run of drain (1·92 cubic foot per square foot of opening) and the quantity in the two ends was 109·5 cubic feet. Thus for a culvert of length L the quantity of concrete used was 17·33 L + 109·5 cubic feet. As no satisfactory data concerning the actual cross breaking-strength of concrete of really cheap proportions were obtainable for designing the tops of these culverts, a rough steel-yard testing-machine was constructed, the load being applied by means of a graduated sand-box. The results of the tests, for the concrete mixture adopted for these culverts, are shown in *Fig. 5*. The beams were

Fig. 5.



RESULTS OF TESTS OF CONCRETE.

6 inches square in cross section, and 2 feet in length between centres of supports. The concrete was taken from the ordinary mixing-boards at bridges, culverts, etc., some of the larger stones only being picked out, before ramming in the beam moulds. The 6-foot and 10-foot arches were formed wholly of concrete; or of rubble in 1 to 5 cement mortar for the abutments, with concrete arching. These arches were generally turned on wooden centres, but in the case of one 10-foot arch the method of earth centres was adopted with success and economy. When the abutments and skewbacks were completed, the space between them was filled in

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with the most convenient materials—sand and earth—and the last few inches were formed with a soft binding loam, which was trued and strickled off to a template run along the skewbacks, the concrete being put in on this form and the earth being dug out as the equivalent of striking the centres. The girder-bridges, when of single span, were constructed with U-shaped abutments. When of more than one span, buried piers were generally used instead of abutments, as being much cheaper, and, when properly protected by rubble pitching, quite as secure. These piers were made of the same proportions as the intermediate piers, up to bed-stone level, so that, in the case of an opening being ultimately increased by adding more spans, it would only be necessary to dig out the bank and remove the ballast wall of the buried pier, when it would become an intermediate pier, and any spans needed could be added at either end of the bridge. All the piers and abutments to girder-bridges were made of concrete, and all the masonry was built to accommodate a future second track.

Foundations.—Piers and abutments of bridges having spans not exceeding 20 feet were built on a block of concrete resting on the natural bottom of the excavation where the foundation was dry, and on a floor of rubble well rammed into the bottom where water had to be pumped, nearly all such spans being on the clayey layers of re-deposited Loess. Most of the bridges of not less than 30 feet span were in wet and comparatively soft ground, and were founded on piles, generally 16 feet or 24 feet in length, the Sander formula being used to estimate their maximum safe load. This formula, in spite of its unscientific character, has from long experience been found satisfactory. A layer of rubble, the surface of which was about 6 inches below the sawn-off tops of the piles, formed, with the pile-heads, the base of the concrete, so that the pile-heads were embedded in the concrete, and the weight of the masonry rested both on the pile-heads and on the whole area of ground covered by the foundation-block, *Fig. 6.* Two of the river piers of the Chü Ma Ho and Pei Ho bridges were founded on oval concrete wells 13 feet by 9 feet, two such wells, with their major axes at right angles to the track, forming the foundation for one pier. These were sunk through sand by means of revolving bag dredgers.

It was decided that the seven channel-piers at Pei Ho should be founded on pairs of concrete wells, sunk by the pneumatic system, as it was certain that for the further extension of the line southwards such a plant would be in continual use. The air-compressors having been ordered in ample time, and air-locks, piping,

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etc., being ready, the curbs, working-chambers and air-shaft were made in the construction workshops and were sent to the site of the bridge, and pitched. Owing, however, to delays by the Chinese Office in Shanghai, and finally owing to a strike in England, it seemed certain by the end of March, 1899, that the machinery would not arrive in time, and that, the permanent bridge not being built, the floods of the summer months would do considerable damage to the works, stop the paying traffic which had been running through to Pao Ting Fu since 1 February, and also, by breaking the line, stop all other work beyond the bridge. It was necessary, therefore, to improvise air-compressors. For this purpose the Author employed two out of the three tank-

Fig. 6.

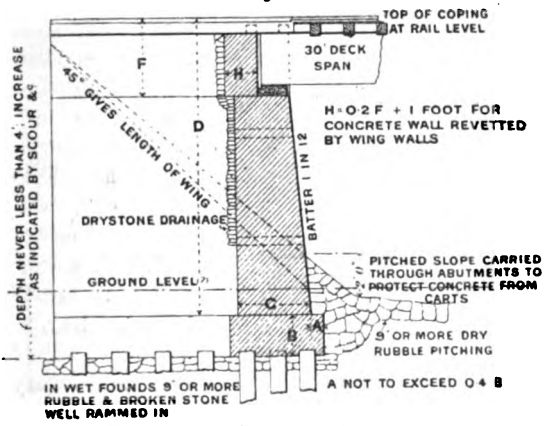
TOP OF COPING AT RAIL LEVEL
30' DECK SPAN
F
H
D
H=0·2 F + 1 FOOT FOR CONCRETE WALL REVETTED BY WING WALLS
45° GIVES LENGTH OF WING
BATTER 1 IN 12
DEPTH NEVER LESS THAN 4' INCREASE AS INDICATED BY SCOUR &c
DRYSTONE DRAINAGE
GROUND LEVEL
PITCHED SLOPE CARRIED THROUGH ABUTMENTS TO PROTECT CONCRETE FROM CARTS
C
B
A
9' OR MORE DRY RUBBLE PITCHING
IN WET FOUNDS 9' OR MORE RUBBLE & BROKEN STONE WELL RAMMED IN
A NOT TO EXCEED 0·4 B

DIAGRAM OF CONCRETE ABUTMENT.

engines belonging to the line. The lap was taken off both ends of one slide-valve on each engine and the valve-motion was set without angular advance, the steam- and exhaust-pipes on that side being disconnected and their ends fitted with blank flanges, while an air-delivery pipe was bolted to the steam-inlet to the valve-box, and a screen was put over the exhaust orifice, now the air-inlet. The keeps of the driving axle-boxes were lined with Babbitt metal to form bearings, the side-rods were removed, and the engine was hauled to the bridge and there jacked up so that the driving-wheels were free to revolve, acting as fly-wheels. The one cylinder under steam now drove the other cylinder as an air-compressor. The lagging of this cylinder was taken off, and a coolie was employed to direct a constant stream of water all over

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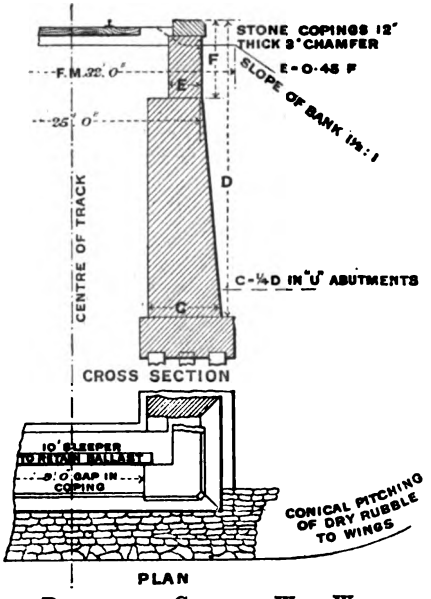
its surface, to keep it as cool as possible. Grease-cups were fitted to the valve-chest and cylinder to lubricate the surfaces, as this could no longer be done with the sight-feed lubricator. The locomotives thus adapted to work as air-compressors worked as smoothly as could be expected, and were perfectly efficient up to the maximum pressure required, about 20 lbs. per square inch. The fourteen wells were sunk with the help of these machines, and the permanent bridge was duly completed before the beginning of the flood season. As soon as the last air-lock was taken off, the engines were hauled back, and in about a week were re-converted to locomotives and put on the road.

Figs. 7.



DIAGRAMS OF CONCRETE WING-WALL.

Concrete Masonry (*Figs. 6* and *7*).—The limestone of the available quarry was so cut up with cleavage-planes that it would furnish no stones suitable for ashlar or block-in-course masonry. The only stone available for copings, etc., was granite, which was costly to quarry, and had, moreover, to be carted to the head of the branch line. It was, therefore, out of the question for ordinary masonry, while, on the other hand, limestone, when broken down, made an excellent and cheap aggregate for concrete. The bricks of the country are wholly unsuitable for bridges and culverts. The stone for concrete was broken by hand, so that an average piece would pass through a 2-inch ring. The proportion of spalls being small and the percentage of voids in such stone being too great to give an economical concrete, the larger stones were picked out, or small rubble was used, being broken down to pass through a ½-inch sieve; this was done at a piece-work rate. In gauging the concrete a proportion of this fine stuff was added, displacing so much mortar in the voids of the larger stones and giving a greater bulk of concrete for

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the same amount of cement and the same strength of mortar, besides a more homogeneous and freer mixture, with less chance of voids in the finished work and greater capacity for consolidation under the rammer and for taking the form of the mould. A mixture composed of 1 of cement to 4 of sand and 8 of broken stone, with 1 of ½-inch chips, is for convenience described as 1—4—(8 + 1), and this gauging was used for box-culverts, U-shaped abutments, and abutments of arches. Piers were made of 1—3½—(7 + 1) concrete, and arch-rings and foundation-blocks over piles of 1—3—(6 + 1) concrete. In every case a layer, 1 foot in thickness, of 1—2—(3 + 1) concrete was laid under the bed-plates of girders. The consumption of cement for the 90 miles of line was some 44,000 barrels, most of this being of German manufacture, "Alsen" brand, packed in iron drums with wooden ends. All concrete work was kept wet for 6 to 10 days by pouring and sprinkling water over it. In the 21-foot piers at Liu Li Ho, three holes, each 6 inches in diameter, were carried up on the centre line of the piers from the top of the plinth to bed-stone level, and were kept filled with water for about the same time to insure the work thoroughly setting, being afterwards plugged.

The cost of imported cement far outweighing the cost of both native labour and all other materials and plant for masonry, it was necessary to exercise special care in order to insure its economical consumption. The natives being careless in gauging concrete, the cubic content per foot of height of all masonry was calculated and noted on all drawings, and for every mixing of concrete an immediate return was demanded of the height put in and the number of barrels of cement used. The evidence of these reports immediately illustrated their necessity. Carelessness and a desire to avoid blame for bad concrete caused great waste of cement. This ceased immediately, however, under the system of checking nightly the volume of concrete deposited per barrel of cement, and little further trouble was experienced. No foreman or ganger was allowed to mix concrete except in the presence of the engineer of the section until his reliability was fully established, and then only under constant check and inspection. The result was excellent work throughout. The question of wet *versus* dry mixing of concrete is mainly an academic one. Whatever the relative value under laboratory tests of a "driest possible" and a wet mixture may be—and this is sufficiently clear from tension tests of both neat cement and mixtures—in actual work, where concrete must be rapidly mixed by hand and placed in large quantities, there is

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practically no great variation possible in the amount of water used. Enough must be used to make the labour required in turning moderate, to make the mixture thoroughly plastic, and to insure the mortar getting in freely between the stones under the rammer or shovel, but so much must not be used that water and slurry collect on top of the work, or that the fluid mortar carries the cement away through spaces in the shuttering, etc. These conditions practically fix an exact proportion of water. Again, in laboratory work the briquette is always given opportunity to absorb water for setting, whereas in massive construction above water-level only the surface layers can be expected to receive more water than is given in the original mixing.

Most of the concrete work was done in hot weather, and set rapidly in consequence, and no extended ramming was possible. Plums of rough limestone-rubble were used where the structure was not subject to direct or considerable transverse stress. They were employed in abutments and piers, but not in foundation-blocks or footing-courses, and were placed so as never to be nearer to the face or to one another than 6 inches in any direction. The stones were soaked in water and then thrown down on, and rammed into, a soft mass of newly-laid concrete. In some few cases it was necessary to continue the concrete work of minor bridges after the frost had set in, in order to avoid delay to the track or the employment of diversions. This was done by carrying out the work on fine days under the hot winter sun, boiling the water of mixture and dissolving 8 per cent. of salt in it and covering the work over each night with a thick layer of straw. Such work has stood well, and only in one case, where the salt or firewood was probably stolen and the work scamped, was it necessary to take down some few feet of a small pier which was found to be touched by frost. The Alsen cement used was packed in sheet-iron drums with ½-inch wooden ends, which were necessary, to stand the tests of transport under Chinese conditions and the exigencies of weather and storage. The drums could be sold to the Chinese when empty, and were also used for temporary shedding, sheathing to timber-work, etc. British makers refused to pack cement in iron drums, and a very serious loss of cement occurred through the constant transhipment and handling of the wooden barrels. The loss from similar causes when iron drums were used was less than one-tenth as much. In no case, except that just referred to, had any concrete to be condemned, or were any cracks due to unsoundness of cement discovered.

General Note on Concrete.—The Author would here call attention

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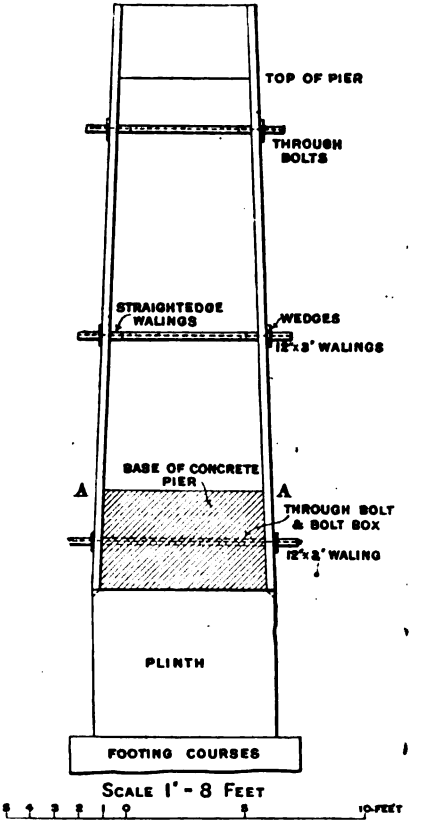
to two apparent anomalies in the general conception of concrete as a material in competition with other masonry:—

1. Concrete appears almost always to be judged and compared with other masonry by its compressive strength, whereas its ultimate test is rarely that of direct compression. Cracks and failures in masonry, whatever the first cause may be, whether from unequal foundations, unequal loading, or direct transverse stress as in a masonry or concrete beam, are almost invariably caused by cross-breaking stress or shearing stress, and therefore, in effect, by tensional weakness or weakness in shear.

2. Although compressive stress is the test adopted, and although concrete generally gives a higher value thus tested than brickwork in cement, still brickwork, at two or three times the cost of concrete, continues to be regarded as a more reliable material.

The Author is of opinion that the transverse breaking-strength of beams having a depth equal to one-quarter to one-half their bearing-length is the best test of materials for masonry work, and if this is true it seems certain that even poor cement-concrete should be preferred to brick much more often than is the case.

Fig. 8.



SHUTTERING FOR CONCRETE.

Shuttering.—Concrete moulds were made of timber, 3-inch planks, placed vertically, being used; these were secured and kept in line by means of deep walings, generally 12 inches by 3 inches, outside the planks, held together by long bolts passing through the con-

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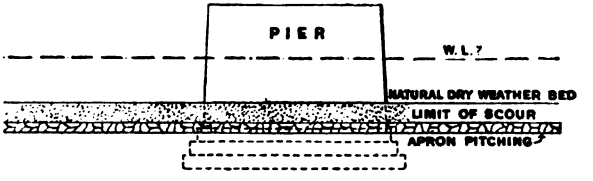
crete. The bolts were enclosed in long boxes of $\frac{3}{8}$-inch timber, in order to be easily withdrawn. After drawing the bolts, the ends of these boxes, for a few inches from the face, were broken out with a chisel, and the holes were plugged with cement mortar. Inside, the planks were planed and kept to line and face by means of straight-edges placed inside them and strutted to the correct distance apart. Wedges were then driven outside, between the walings and the planks, to bring the latter up to the straight-edges. The moulds were taken down about 36 hours after the last concrete was placed, any voids in the face were picked out clean and pointed with cement mortar, and the whole surface was then rubbed down with boards, using sand and water under them, to secure a uniform surface. In the case of the Liu Li Ho piers, which had a height of 21 feet in one straight taper above the plinth-course, the shuttering was fixed to the last concrete made. A separate mould about 4 feet in height was made and set upon the plinth, and in this concrete was deposited up to the level AA, *Fig. 8*, bolt-boxes being left through the concrete. When the

Fig. 9.



RUBBLE APRON TO PIERS.

concrete had set, the planks for the remainder of the height were bolted together on to this base, thus securing great stability and saving much work in scaffolding, etc. In all moulds more than about 8 feet in height a door was left in the shuttering to allow the lower portion of the concrete to be carried in more easily.

Protection of Bridges.—The beds of all rivers and streams where scour was anticipated were protected by aprons of rubble, *Fig. 9*, the level of the top of the rubble being that of the probable average depth of scour in a heavy flood, or, where it was impracticable to get down to this level with economy, 1 foot below that of the normal stream-bed at the opening. In the case of small culverts, etc., where the invert-level could not be put very low for fear of silting, the bottom pitching at both ends was sloped downwards until it was well below the level of any probable erosion. Plinths and footing-courses were also provided with cut-water ends

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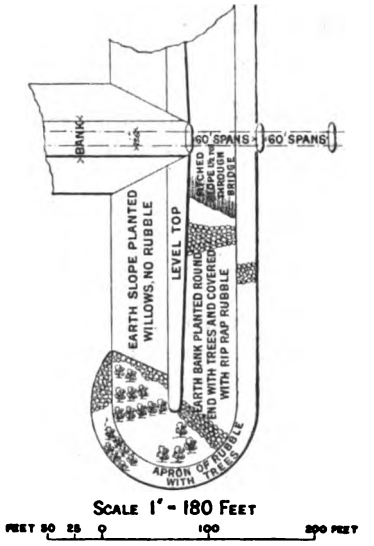
to diminish the eddy effect in case of scour getting down to their level. In the larger flooded valleys where the up-stream water swirls round into the rapid current through the bridge, an eddy is formed which endangers the abutments and the banks near them. In these cases training-banks were run out at right angles to the bridges, and were protected with rubble facing and trees, *Fig. 10.* The effect of these is to give a straight path for the water through the bridge, and to remove the eddies and disturbed water to a point at a safe distance from the abutment and bank, where any damage can be cheaply repaired without injury to the permanent structure and running line. The maximum length of training-wall provided in any bridge was half the length of the total opening, but each case was treated on its merits according to its situation and the observed or estimated current it would experience. For the protection of banks from the scour of side-cuts, tree-planting was extensively employed, the whole line having trees and scrub planted along it, and all banks on low-lying or flooded ground having three rows, sometimes on one side and sometimes on both sides of the line. Most of this planting was done by petty contract for supply and planting. For three rows having sticks 1 inch to 2 inches in diameter and 5 feet apart, the sticks being 3 feet in length, and the small twigs and scrub planted between the rows, about $\frac{3}{4}d.$ per yard of treble line of planting was paid. For trees 9 feet in height by 3 inches in diameter 3*d.* each was paid. The sticks and twigs, which are generally willow, are planted as soon as, or before, the frost is quite out of the ground, and when planted thus early they rarely fail to take root and grow well.

Fig. 10.


BANK
60' SPANS
60' SPANS
ARCHED OPENING THROUGH BRIDGE
EARTH SLOPE PLANTED WILLOWS, NO RUBBLE
LEVEL TOP
EARTH BANK PLANTED ROUND AND WITH TREES AND COVERED WITH RIP RAP RUBBLE
APRON OF RUBBLE WITH TREES
SCALE 1' = 180 FEET
FEET 50 25 0 100 200 FEET

PLAN OF TRAINING-BANK.

Erection of Girders.—The majority of the minor bridges were temporarily spanned with timber baulks, and the construction traffic was run over them before permanent girders were ready. In this case the spans were sent out from the shops riveted and

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complete, and were unloaded on the side of the double formation, and slipped into place by a gang of coolies, between trains or at night. The 60-foot spans were sent out from the bridge-yard at Shan Hai Kuan, two single girders at a time, on a special 70-foot flat car. These were unloaded at the side of the formation and near the bridge, from a siding on the top of the bank, the traffic meanwhile being taken by the diversion round the bridge. They were then erected over the track on the bank, and the bracing was riveted up complete. The girder was then jacked up, and, resting on two ordinary plate-layers' trolleys placed at the ends, was run over the light temporary bridging and lowered into place with jacks. The temporary bridge was then shifted to the next span, and the next girder was run out over the first and the temporary bridge and lowered, and so on. This method gives solid ground and plenty of room for proper erection and riveting, while leaving the minimum possible amount of field-work, and necessitating no heavy false-work, staging, or lifting. The girders ordered direct from home were sent in sections to the site of the bridges, and were erected and riveted there, and run over to place in the same manner. Owing to pressure of work on the Manchurian extension at the time, it was impossible to adopt the method, universal on the Imperial Chinese Railways, of sending out the 60-foot spans complete from the shops, slung on two cantilevers over trolleys, from which the finished span is lowered by means of crab-winches. All the girders were of the deck type, as it was always cheaper to raise the level than to pay for the additional weight of half-deck girders. The decking was of sleepers, 8 inches by 8 inches, by 10 feet in length, notched and bolted to the upper flanges and provided with a guard-rail of Oregon pine, 6 inches by 6 inches.

System of Construction.—The general plan of construction was to lay a road through as soon as the earthwork was completed, diverting the line at all bridges of more than 10 feet span. The minor bridges near the rock-cutting, for the first 10 miles, were completed before the rails were laid, with ballast carted from the cutting, and, owing to delays in the arrival of the track materials, a few other minor bridges were also completed with materials carted from the hills. The great bulk of the work, however, was carried out on each section after the rails had been laid past it. Temporary timber bridges on piles, of sufficient length to pass the winter and spring streams, were erected over the larger rivers, and diversions having gradients of 1 in 100 and curves of 1,000 feet radius led down to these or round the drier water-courses, the reason for using easy gradients and curves being that the earth-

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work on these diversions was very light, and the cost per yard almost nominal; while, on the other hand, it was intended to use heavy engines and long trains to save locomotive running and delay in construction, the cost of these items being considerable. The trifling additional expenditure necessary to obtain an easy road was fully justified. Trains of thirty to forty low-side bogie-cars, each having a capacity of 500 cubic feet, served the bridges, depositing ballast, rubble, cement, and sand as required. Piles and pile-drivers were sent by water-carriage as far as possible and thence carted, so that pile-driving for permanent bridges was in all cases finished before the rails reached the bridges. A pony-track was made along the route at the commencement of construction and a telegraph-line was erected. Pile-driving, concrete and masonry work, carpentry, brick-laying, riveting and erection of girders, and all shop-work, were done by time-labour, as only in this way could thoroughly sound work be secured.

Rails and Rail-laying.—The Chinese, being desirous of using their own rails, rolled in Wu Chang, near Hankow, and it being a matter of "face" that, having established a steelworks, its product should find practical application, these rails were used for all but some 30 miles of the road. Two sections, one of 72 lbs. per yard and one of 85 lbs. per yard, were supplied. These were of steel containing too high a percentage of phosphorus. They varied in height and section and in the bearing of the fish-plates, and so made a bad road. The lighter section was used for the branch line and for sidings. The 85-lb. rails were of variable quality of steel. The fish-plates were not a proper fit, the height of the rail varied, and no arrangement was provided for spiking the fish-plates to the sleepers, in consequence of which considerable creep occurred, and it was ultimately necessary to have all these plates slotted by hand, under contract with native smiths, the joints re-squared, and the plates spiked to the joint sleepers. The joints being so bad, it was decided to try a section of line with staggered joints, the joint of one rail being placed opposite the centre of the opposite rail. This was a very decided success and the running (under the existing condition of bad joints) was very greatly improved, the joints being felt almost as little on this section as on the 30 miles laid with English rails. The latter were of Sandberg 1894 pattern, weighing 85 lbs. per yard, with Goliath fish-plates, and made excellent track. They were 30 feet in length, and were spiked to Oregon Fir and Japanese sleepers without base-plates. Thirteen sleepers, 8 feet by 6 inches by 9 inches, were put under one pair of rails. The Chinese rails, having a narrow base, were

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laid on base-plates. Owing to the slow delivery of rails from Wu Chang, no satisfactory progress could be made with rail-laying, which was commenced in January, 1898, the rails not reaching Pao Ting Fu till the 20th January, 1899. One mile per day could have been accomplished without difficulty if supplies had come forward, and a length of 2 miles was on one occasion laid in a day, but, as it was, construction was seriously hindered. Traffic was opened provisionally in sections as the rails advanced, and the takings became considerable even before rail-laying was completed; on the 1st February, 1899, a regular through-service of two trains each way per day was opened between Lu Kou Chiao and Pao Ting Fu. A 2-foot gauge portable track of ½ mile to ¾ mile in length was used to bring forward the rail-laying material on trolleys, this track being laid on the free side of the double bank. Material was brought forward over the unballasted track by six-wheels-coupled tank-locomotives, of about 30 tons weight, and as ballasting proceeded was brought over the ballasted section by heavy locomotives of the "Mogul" class. Chinese labour is excellent for plate-laying work, after a short period of training and under constant supervision, the quality of the work done depending only on that of the supervision.

Ballasting.—Gravel ballast from a river-bed was used, the price paid for loading being about 1*d.* per cubic yard, and the average lead about 33 miles. The line was ballasted in two lifts. One-half the contents of each car was first unloaded on to the track, and the train was then moved on for its own length and the remainder unloaded. In this way ballast was spread for about ¾ mile per day. This ballast was sufficient for 4 inches to 6 inches lift, and was put under by petty contract at ½*d.* per lineal yard, and ¼ mile to ½ mile per day was covered by this gang, who were followed by the permanent maintenance gangs with an extra force of surface-men to get the track into good running order. When the whole line was thus half-ballasted, and the large tender-engines enabled to run over it, the remainder of the ballast required was unloaded, and the final lift was given by a second gang, paid by time and under a Chinese foreman, the maintenance men finally boxing and trimming after a good surface had been secured. One great incidental advantage of this ballasting in two lifts is that the ballast is never unloaded in such quantities as to clog the wheels of the cars or leave dangerously large and high heaps by the side of the permanent-way. The cars used were the standard low-side bogie-cars built by the Imperial Chinese Railways at Tong Shan, having four side-openings, and of 500 cubic feet capacity. The

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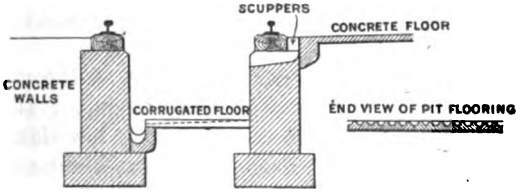
unloading of ballast, as well as of all other materials, was done by a gang working at a schedule of piece-work rates, foreign steel long-handled shovels being supplied to them.

Stations and Buildings.—There are ten stations on the main line and two on the branch line. These were set back away from the track, in order to leave ample space for future sidings. The platforms for third-class stations are 400 feet in length, and have brick platform-walls with granite copings; the platforms of second-class stations are 600 feet in length. Loop-sidings for passing trains have a length of not less than 1,500 feet, and accommodate a train of forty bogie-cars and tender-engine. The ticket-offices include quarters for a station-master, a telegraph clerk, ticket sellers, etc., and are built of native brick, with iron roofs. At Liu Li Ho, the junction for the branch line, a running-shed for two tender-engines, a 20,000-gallon water-tank with a steam-pump, a coal-loading stage, etc., are provided. At Pao Ting Fu there is a shed for six engines

Figs. 11.



Cross-Section of Running-Shed Pit.

and a tank and pump of the same size. There are also smaller tanks supplied by hand-pumps at two intermediate stations, and one on the branch line. The water is only moderately good for North China, some wells having 20 grains of solid matter per gallon.

The floors of the running-shed pits (*Figs. 11*) consist of concrete slabs corrugated on the surface, the tops of the corrugations being level and the bottoms sloping downwards across the pit, towards the longitudinal side-drain. The effect of this is to give an absolutely dry and clean footing under all conditions. All the surfaces being curved they are easily cleaned, and an iron grating can be put over the drain if desired. The slabs were made in moulds with the corrugations downwards, and these were made of a fine concrete, while the greater mass of the slab was gauged 1, 3 and 6. The contract system was adopted tentatively for pumping, the coolies being paid according to the indication of the tank gauge and the drivers' receipts, and was

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found to be economical in working. It seems probable that pumping by mule-labour will prove to be the most economical system where steam-power is not employed. A triangle was used at the junction for turning tender-engines, and three others were put in during construction for temporary use while ballasting and hauling materials. As there was plenty of room, these triangles were laid out with curves of 600 feet radius, the rails being spiked on base-plates and laid to $\frac{3}{8}$ inch slack gauge. There is a 55-foot turntable at Pao Ting Fu, which will be permanently an engine-changing station. Houses for the permanent gangs of surface-men were built at every 10,000 feet. These are brick cabins, 30 feet in length by 9 feet in width inside, giving sufficient accommodation for the six men who lived in them. Native-tile roofs were used for these, but are scarcely safe against the occasional hail-storms, in which hail-stones well over $\frac{1}{4}$ lb. in weight are not uncommon. Mileage, gradient and bridge number-posts are all of stone, as timber is liable to be stolen. Fencing is practically impossible for the same reason, and is seldom needed except at stations. Gradient-stones face the train, and are of Imperial Chinese Railways pattern.

Rolling Stock.—The vehicles were all made at the car-shops of the Imperial Chinese Railways in Tong Shan, of their special standard type, and consist of one hundred low-side bogie-cars capable of conversion to high-side cars, one hundred high-side bogie-cars, twenty 30-ton high-side coal-cars, seventeen passenger-cars 60 feet in length, and bogie brake-vans. The three shunting-engines used for construction work were six-wheels-coupled side-tank engines having cylinders 15 inches in diameter and 20 inches piston-stroke, and weighing about 30 tons; and the tender-engines for main-line work are "Moguls," or six-wheels-coupled, with a leading pony-truck, the axle-load being 16 tons on the driving-axles and 10 tons on the pony-truck axles, and the total weight of the engine without tender being 58 tons. The Janney coupler is used on all stock, and has become the standard for all Chinese railways.

Traffic.—Traffic was only partially developed on the line when the Author left it, and the monthly receipts are not available for this Paper; but it may be said that, after running for 8 months and before the permanent line was wholly completed, the traffic receipts were at a rate sufficient to pay working expenses and a fair rate of interest on capital expenditure. There was every indication that the next financial year would have resulted, to a private company, in a very substantial dividend on the capital cost of construction. The chief items of traffic were coal, grain, and

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passengers; lime and stone, pigs, mats and other general merchandise were also largely carried. In every case the traffic consisted of that previously existing, carried by train instead of on the roads, and although this will be greatly increased by the facility given, it is not chiefly by creating traffic, but by adopting that already existing, that this and other railways in China will be made to pay. Other engineering works, however, such as the working of coal-mines by foreign methods, the construction of harbours, the establishment of industries on a foreign basis of output, will, of course, have the same influence on traffic as elsewhere.

The following are the rates and fares fixed by the Chinese directorate of the Lu-Han Railway:—

	d.	
First-class passenger, about	0·86	per mile.
Second-class „ „	0·43	„ „
First-class goods „	1·38	„ ton-mile.
Second-class goods „	1·15	„ „
Third-class „ „	1·00	„ „
Fourth-class „ „	0·83	„ „

These passenger fares are about one-and-a-half times as great as those on the older Imperial Chinese railways, the freight rates being about the same. The special rate for coal and lime was 0·423*d.* per ton-mile plus 3*d.* per ton terminal charges.

First-class goods include raw cotton, skins, kerosene oil, wine, furniture, mats, etc.

Second-class goods, cotton piece goods, tea, meat, vegetables, etc.

Third-class goods, rice, grain, flour, metals, machinery, etc.

Fourth-class goods, stone, bricks, sand, etc.

The average cost of coal for the engines was about 10*s.* per ton on the coal-loading bank, but has been raised to double this rate since the war.

At Liu Li Ho, where it was desired to effect connection between the railway and the river, the water occasionally rises in flood 20 feet or more. The native warehouses and store-yards are therefore on the high ground, and are about 25 to 30 feet above the level of the river throughout nearly the whole year. The merchants purchased a considerable area of ground in a convenient situation adjoining a creek of the river, and on this sidings were laid. The rest they were allowed to arrange themselves. They deepened the waterway to take loaded boats and constructed several ramps from the water to the level of the high ground, below which the rails were laid in shallow cutting to give the elements of a loading-bank. This was all they required for a considerable trade, and any further expenditure

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would have been lost. All goods were carried up and down the ramps by coolies, and it is improbable that any modern appliance or machinery could have effected the work as cheaply.

Workshops.—The construction-shops of the Imperial Chinese Railways being far distant and pressed with work for the northern extension, temporary construction-shops and stores were arranged at Lu Kou Chiao, which was connected by rail from the commencement of the work with the Peking-Tientsin line. Here caissons, curbs, air-shafting, tanks, and a large number of the smaller girders were made, plant was erected and prepared, pile-drivers were built, etc. The Author took over charge of these works early in 1899.

Cost of the Work.—The cost of the work cannot yet be ascertained exactly, but was approximately the following:—

	£
Expenditure in China, including proportion of rolling stock	196,000
Expenditure abroad, including locomotives	258,000
	454,000
Deduct for 10-mile branch	30,000
	424,000

giving £5,300 as the average cost per mile of the main line. The total amount spent on foreign material for 90 miles of line was £258,000. Thus for every mile of railway built in China under British auspices it may be said that this country profits, potentially at least, to the extent of over £2,800.

The Belgian Syndicate having secured the concession for the construction of the whole railway from Peking to Hankow, the Author commenced handing over the work in July, 1899, to the party of engineers sent from France, and left it in September of the same year.

For permission to publish the foregoing Paper, the Author desires to thank Mr. C. W. Kinder, C.M.G., M. Inst. C.E., Engineer-in-Chief of the Imperial Chinese Railways, under whom he served as Resident Engineer. His acknowledgments are also due to the assistant engineers on the work, namely, Messrs. E. H. Rigby, Assoc. M. Inst. C.E., C. V. K. Lagerholm, J. C. Martin, B.E., E. H. Mitchell, Assoc. M. Inst. C.E., and W. O. Leitch, Assoc. M. Inst. C.E.

The first section, including the large bridge of seventeen spans of 100 feet each, double track, over the Hun River, and the shops, was not in the Author's charge during construction, but was

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carried out by Captain W. B. Norregard, under the orders of Mr. A. G. Cox, Assoc. M. Inst. C.E., district engineer of the adjacent Peking-Tientsin line.

The Consulting Engineers in England to the Imperial Chinese Railways are, for bridges, Sir Benjamin Baker and Mr. A. C. Hurtzig, MM. Inst. C.E., and for rails Mr. C. P. Sandberg, M. Inst. C.E.

The Paper is accompanied by a tracing and four sunprints, from which the Figures in the text have been prepared, and by the following Appendix.

[APPENDIX.

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APPENDIX.

The Hun Ho bridge crosses the torrential Hun River about ½ mile above the historic Marco Polo bridge, and also takes the water passed by another river of considerable size. The piers are founded on pairs of pointed ovoid wells of concrete, sunk by compressed air through a river-bed consisting of large boulders and gravel. These wells are continued upon piers, and are connected under the girders by arches having iron ties embedded in the concrete. This shape of pier was adopted to minimize the scour due to a very rapid current and a moving bed, and has proved most successful in this respect and convenient for purposes of sinking.

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(*Paper No. 3374.*)

"Erection of the Nairne Viaducts, near Adelaide, South Australia."

By WALTER EDMUND COOK, M. Inst. C.E.

THE construction of the railway between Adelaide, South Australia, and Melbourne, Victoria, was commenced, at the Adelaide end, in the year 1879. The viaducts described in the following Paper occur in the first portion of the line, and span two deep ravines, close together, situated in the very rough country met with in the Mount Lofty Ranges, about 8 miles from Adelaide.

On this part of the line there occur, in succession:—a tunnel, 17 chains in length, in which the formation-level is 200 feet below the surface at the deepest part; an open cutting of about 1 chain in length; No. 1 Viaduct, 360 feet in length and 106 feet in maximum height from surface to formation-level; a shallow bank, not quite 2 chains in length; and No. 2 Viaduct, 260 feet in length and 78 feet in maximum height. Crossing the viaducts, the line is on a curve of 10½ chains radius, the curve extending from 2 chains inside the tunnel north of No. 1 Viaduct to 10 chains into a deep cutting at the south end of No. 2 Viaduct.

At the Garden Palace Exhibition, opened in Sydney, N.S.W., towards the end of 1879, one of the most interesting engineering exhibits was one span of a road-bridge to be erected over the Shoalhaven River by the Edgemoor Iron Company of Philadelphia, U.S.A. Taking advantage of the presence of Mr. Onward Bates, M. Inst. C.E., the Company's Engineer, in Australia, Mr. H. C. Mais, M. Inst. C.E., then Engineer-in-Chief of South Australia, invited him to submit a design for the viaducts. After some slight alterations made by Mr. Mais, the design and strain-sheets were submitted and agreed upon, and a contract was entered into for the supply and erection of the ironwork. The whole of the ironwork and erecting-gear was on board ship in New York Harbour within 30 days of the receipt of the plans and specifications at the Company's office in Philadelphia.

No. 1 Viaduct is made up of twelve spans of 30 feet, whilst No. 2 Viaduct consists of eight spans of 30 feet, and one span of

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20 feet at the south end, Figs. 1, Plate 5. Each alternate bay is braced longitudinally as well as transversely, so as to form virtually a rigid column. For the intermediate bays the main girders span the 30-foot opening from one such rigid column to the next. Pier 1 of No. 1 Viaduct, and Piers 5 and 8 of No. 2 Viaduct, unlike the other piers, consist of hinged posts, allowing a rocking motion in the direction of the length of the viaducts. Each leg of each pier stands on a separate concrete base, as shown in Figs. 1, Plate 5. These and the concrete abutments had been built by Government day-labour before the arrival of the iron-work, as they formed no part of the work contracted for, although included in the design.

The ironwork was shipped in 30-foot lengths, or even greater lengths in the case of diagonal braces, so that little riveting or bolting was necessary after getting the pieces into position. The material having been carted to the spur between the two viaducts, a wooden-framed crane, having a fixed horizontal overhang of about 32 feet, was erected at the south abutment of No. 1 Viaduct. The legs of Pier 11 were swung into position, and the transverse bracing was fixed without securing the base-plate by any holding-down bolts. The horizontals are small lattice-girders, and the diagonals are 1-inch and $1\frac{1}{8}$-inch tie-bars with adjustable screws, Figs. 3, Plate 5. The main girders for this bay were then placed in position, and were secured by temporary drift-bolts. The crane was then run forward on four wheels of small diameter, which were narrow enough to pass between the rivet-heads of the top member of the main girders. It was securely fixed to the girders when the main verticals of the crane were just over Pier 11, so that the outer ends of the horizontal arms were over the line of Pier 10. The work was then carried on as in the first bay, with the addition in this case of the longitudinal bracing, before proceeding with the next bay, and meanwhile the riveting of braces, fixing of buckle-plate decking, etc., were going on in the first bay. These operations were repeated till the whole viaduct was completed. The fixing of the holding-down bolts at the base of the pier-legs was the final operation, holes being drilled by hand in the concrete bases through the holes in the base-plates. The design was extremely simple in character, although very effective, and lent itself to this simple and rapid method of erection without staging.

A notable feature of the structure is the complete accessibility of the parts for examination and painting, so that with ordinary care in maintenance it should last for years, unless the weight per

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axle of the locomotives should be materially increased, when new and stronger cross-girders would be required. To prevent damage should an engine or carriage leave the rails, a longitudinal balk of timber, 12 inches by 6 inches, is bolted to the sleepers (which are spaced 2 feet apart, centre to centre) 10 inches from the face of the upper rail, the top corner being faced with 3-inch by 3-inch by $\frac{7}{16}$-inch angle-bar. Between the foot of the rail and this balk an iron plate, 6 inches by $\frac{3}{4}$ inch, is fixed on the sleepers. On the inner side of the lower rail an iron plate, 8 inches by $\frac{3}{4}$ inch, and a steel guard-rail $4\frac{1}{2}$ inches in height are fixed, Fig. 2, Plate 5.

The contract price for the supply and erection of ironwork was £40 per ton for a little over 250 tons, the girders weighing 138 tons and the legs 112 tons. The concrete bases and abutments, including excavation of foundations, cost £3,480, thus bringing up the total cost to £13,490. As the total length of deck is 620 feet, the cost per foot run was not quite £22.

The setting-out of the concrete bases, which had to be done very accurately, was rendered extremely difficult by the rough nature of the country, the slopes, especially at the tunnel end of No. 1 Viaduct, being so steep that steps had to be cut to enable the workmen to climb up and down, while it was almost impossible to set up an instrument at all. When the ironwork was finished everything was found to be absolutely correct. The setting-out was done partly by Mr. J. Stirling and partly by the Author, who were assistants to the late Mr. P. Galt, Resident Engineer. Mr. R. C. Patterson, M. Inst. C.E., Deputy Engineer-in-Chief, acted as Inspecting Engineer throughout the construction of the railway, and gave special attention to these viaducts.

The present Engineer-in-Chief, Mr. A. B. Moncrieff, M. Inst. C.E., recently reported that the viaducts have been used for public traffic for 19 years, and are in first-class condition and perfectly safe.

The Author is indebted to Mr. H. C. Mais, M. Inst. C.E., for particulars of cost and other details given in the Paper.

The Paper is accompanied by three photographs illustrating the method of erection of the viaducts; and by three tracings, from which Plate 5 has been prepared.

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(*Paper No. 3344.*)

"Dry Dock at Riley's Hill on the Richmond River, New South Wales."

By ALEXANDER DONALD CRAIG, B.E., Assoc. M. Inst. C.E.

THE Richmond River, one of the principal coastal rivers of New South Wales, enters the sea after a course of 62 miles, navigable for ocean-going boats. The importance of the surrounding district was early recognised, and its development has been continuous, the principal exports being timber and agricultural produce. Hitherto one of the chief obstacles to the development of the producing industries has been the bar at the mouth of the River, and a comprehensive scheme for the improvement of the entrance is now being carried out by the Government. As this work is being executed by day-labour, a large floating equipment consisting of punts for carrying stone, tugs, dredgers, etc., has to be maintained, and it therefore became necessary to provide docking facilities in order to obviate the necessity of going to Sydney for repairs.

The circumstances existing on several of the coastal rivers in New South Wales are, in general, very similar to those just described, and docks have recently been built by the Government on the most important of these rivers, namely, the Tweed, the Richmond, the Clarence, the Macleay and the Crookhaven Rivers. In the following Paper is presented a description of the dock which is now being completed at Riley's Hill, on the Richmond River.

The most suitable site for the dock was at first the subject of some diversity of opinion, which resolved itself mainly into the question of whether it should be built at Riley's Hill, 20 miles up stream, or at the seaport town of Ballina, but the cost of building the dock at Ballina would have been so great as to have caused its abandonment in favour of a slip, and the site at Riley's Hill was therefore decided upon.

Work was commenced in 1899 under Mr. T. W. Keele, M. Inst. C.E. (now Principal Engineer for Harbours and Rivers), as District Engineer, Mr. C. W. Darley, M. Inst. C.E., being Engineer-in-Chief for Public Works to the Government, and has been continued, at first under Mr. W. E. Kemp, Assoc. M. Inst. C.E., and later under

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Mr. T. E. Burrows as District Engineers. The Author has been Assistant Engineer in the district since the early stages of the work.

Description of the Dock.—The length of the dock was originally determined with reference to the longest Government craft likely to require it, and was thus fixed at 99 feet in the clear and 110 feet 6 inches to the inside edge of the sill. On the sand-pump dredger "Dictys," which was working in the River, being fitted with Higgins rock-cutting machinery, which increased her total length to 113 feet, it was decided to increase the length of the dock to 164 feet clear and its width from 42 feet to 45 feet. Later, however, representations were made as to the great increase in usefulness which would accrue if the dock were made long enough to accommodate the largest of the vessels trading to the River, viz., the S.S. "Tomki," whose length is 180 feet. The length was accordingly further increased to 198 feet clear and 210 feet to the inside edge of the sill. The depth on the sill was left unaltered, viz., 10 feet at high-water, *Figs. 1.*

The pumping arrangements consisted, in the first design, of a centrifugal pump, having an 8-inch suction-pipe, worked by a vertical engine with steam from an 8-HP. vertical boiler. On the final increase in the size of the dock the whole of this plant was duplicated. The suction-pipes lead from a well at the side up through the side-walls to the pumps, which are situated in a building 25 feet from the side of the dock; the 8-inch delivery-pipes discharge through the pump-wells into 18-inch stoneware pipe-drains, which discharge into the River. The gates are 25 feet 6⅜ inches in length on the centre-line, in plan, and the mitre-posts and heel-posts are 13 feet 5 inches and 15 feet 1 inch in height respectively. The mitre-posts are of red cedar and the counterpoise beams of ironbark; the rest of the framing and planking is all of tallow-wood. The horizontal meeting-faces closing on the sill are formed with a rounded nosing. The framing is fastened together by ½-inch wrought-iron plates on each side, sunk flush and secured with 1-inch bolts. Each gate, with its counterpoise beam, is stiffened by two adjustable tension-rods, 1¼ inch in diameter. The pintles and shoes are of cast iron, turned on the bearing surfaces and set with a slight eccentricity from the axis of the heel-post in order to ensure tight closing all round when the gates are shut. The upper hinges correspond exactly in eccentricity with the pintles, and consist of adjustable wrought-iron straps and collars and cast-iron anchor-plates. A sluice-door 2 feet 3 inches square is provided in one of the gates, and is worked from the top beam by a vertical screwed rod 1¼ inch in diameter.

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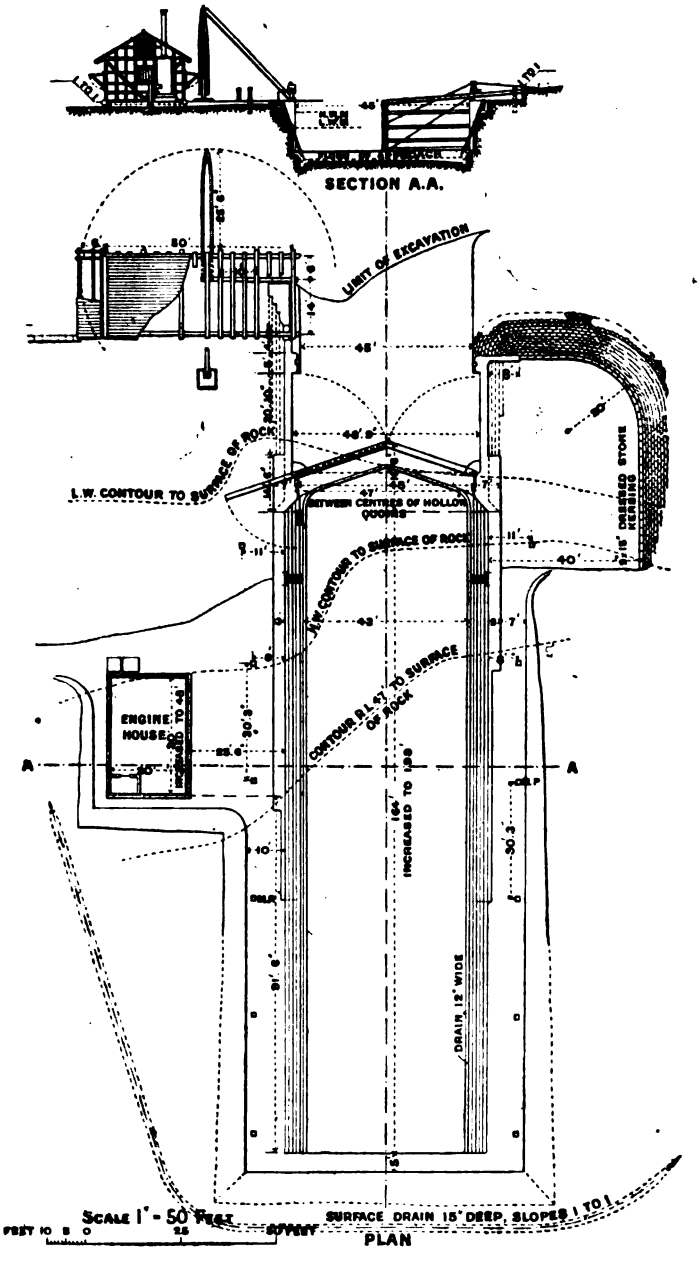
Figs 1.


SECTION A.A.
LIMIT OF EXCAVATION
L.W. CONTOUR TO SURFACE OF ROCK
BETWEEN CENTRES OF HOLLOW QUOINS
PITCHED STONE PITCHING
ENGINE HOUSE
CONTOUR R.L. 47 TO SURFACE OF ROCK
INCREASED TO 136
DRAIN 12' WIDE
SURFACE DRAIN 15' DEEP, SLOPES 1 TO 1
SCALE 1" = 50 FEET
PLAN

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A wharf 50 feet in length by 20 feet in width, with passenger steps at one end and a 5-ton hand-crane on the deck, has been built alongside the entrance to the dock. The wharf is of timber, the piles being ironbark sheathed with Muntz metal and sunk and concreted into the rock to depths of 2 feet 8 inches to 3 feet. The piles were put in in the dry, the space being enclosed by the coffer-dam.

Construction of the Dock.—In carrying out the work the first step consisted in stripping off the soil and bouldery subsoil overlying the rock; the rock was then excavated down to the level proposed for the top of the side-walls. The material was loaded into carts directly and tipped along the river bank. The excavation in rock was effected in the usual way by blasting, both steam and hand drilling being employed. The excavation of the dock proper below coping-level was then proceeded with; the material was removed by means of hauling-gear worked from a steam-winch, raising the material in large scoop-shaped buckets and depositing it in trucks. It was then run out along a short length of railroad by horses and tipped along the river bank. Such stone as was suitable was run on to the steam-cranes and loaded into punts for use in the breakwaters. The excavation was carried as deep as was necessary, even before the coffer-dam was built, by leaving a strip of the rock standing between the excavation and the river. With the exception of one or two weeps, this wall of rock proved quite water-tight. As the excavation proceeded, the sheer-legs were superseded by a steam-crane, which was able to reach over a larger area. By moving it as required along the side of the dock the whole of the excavation could be dealt with. After the completion of the coffer-dam, the strip of rock which had been left as temporary protection was taken out, and the excavation was carried forward to the required contour of the bottom. The excavation at the back end for the last authorised extension, which is still in progress, can of course be carried down to its full depth by utilizing the dock-gates.

An inspection of the bed of the river by a diver, on the proposed site of the coffer-dam, showed that it was strewn with large boulders having deep crevices between them. A grab-dredger was employed to remove this loose material, and some of the boulders which were too large for the bucket had to be slung below water by a diver. When the bottom had been cleaned down to what appeared to be a good uniform surface of rock, holes were drilled in it to receive the dowels for fixing the piles of the coffer-dam. The dowels were of iron, 2 inches in diameter and

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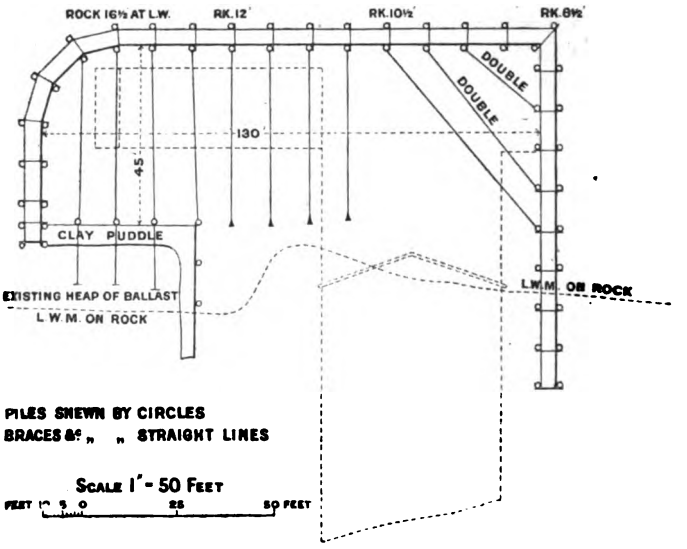
2 feet 6 inches in length, and were set for half their length in holes bored in the toes of the piles. These ends of the piles were bound by iron rings, 2 inches by ½ inch, and the toes were not cut off square, but were fitted to the inclination of the rock.

Coffer-dam.—The coffer-dam was rectangular in plan, enclosing the area for the timber wharf alongside the dock as well as that required for the work at the entrance to the dock itself, *Fig. 2*. It was 130 feet in length on the inside, in the direction of the river, and 90 feet in width at the down-stream end; at the up-

Fig. 2.



PLAN OF COFFER-DAM.

stream end a return portion had to be put in to wall off an existing heap of rubble which could not otherwise be made tight. It was constructed of two rows of piles, 6 feet apart, the piles being spaced 10 feet centre to centre in the rows, and braced together by collarties, *Fig. 3*. To each row of piles a series of horizontal walings was bolted, and inside these the sheet-piling was set, being of 3-inch Oregon pine and local red mahogany on the inside, and 2½-inch turpentine on the outside. The space, about 3 feet 6 inches in width, between the rows of sheet-piling was filled with clay-puddle, for which purpose some of the subsoil on the site was found suitable; the clay core was consolidated by ramming in the

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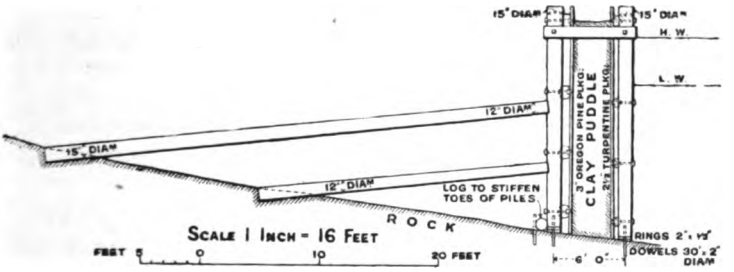
usual way, and also by driving lumps of "pug" down into the mass by the pile-driving monkey.

Damage done by Teredo.—Riley's Hill being 20 miles from the mouth of the River, the percentage of salt in the water is often very low, and the activity of the *teredo*, which is considerable even at the mouths of the rivers of New South Wales, and increases (within wide limits) with the freshness of the water, is therefore very great at this place. In removing the timbers of the coffer-dam on the completion of the entrance-work, it was observed that the scrub-box piles had stood well, being practically untouched by *teredo* after 8 months' exposure, while all the black-butt piles under the same conditions were completely eaten through, and the bloodwood piles were also much damaged. The black-butt piles and walings and the Oregon

Fig. 3.



Cross-Section of Coffer-dam.

sheet-piles in the inside row were quite eaten through, although none of them had been exposed to the *teredo* longer than about 5 months; and during part of that time the Oregon pine had been protected on one side by the clay filling, which is known to prevent the access of the *teredo*; some of these timbers were so riddled that they could scarcely be taken out in one piece. The outer row of sheet-piling was of local turpentine, which is known to have great power of resistance to the *teredo*, a fact which was confirmed in this case, as only three pieces out of the whole row had been touched after 8 months' exposure, and these were not seriously affected. It is surmised that these three pieces may have been cut from a dead tree, as the resistance of this timber is due to some property of the sap. After the dam had been built and the upper shores placed in position, the water inside was lowered so far as to allow of the lower shores being set. On 19 January, 1901, it was pumped

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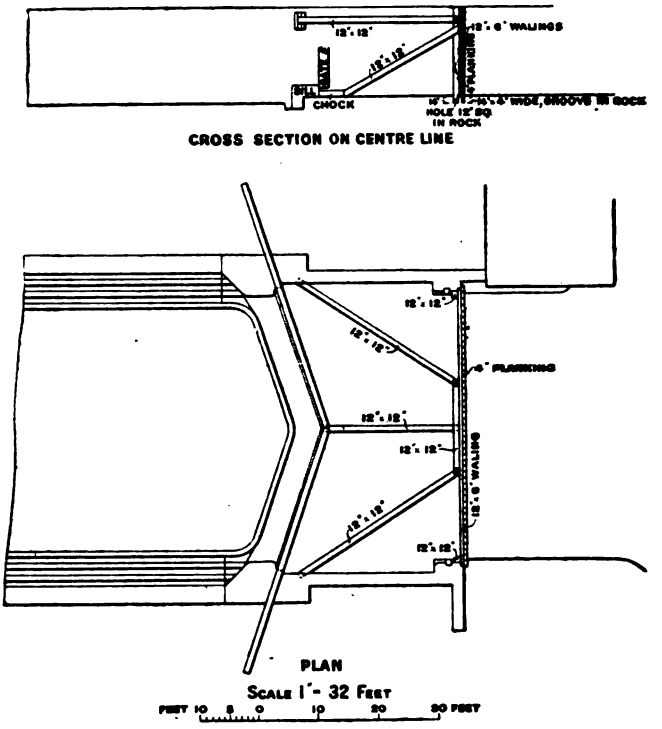
out low enough for holes to be drilled in the rock for the back row of wharf piles; it was then nearly empty and the dam itself was found to be water-tight, some slight leakage, however, taking place underneath it.

In August, 1901, the gates were completed and fixed in position; they were then tested by letting the dam fill up with the gates

Figs. 4.



TEMPORARY COFFER-DAM.

shut The result showed a very small amount of leakage, which occurred chiefly along the face of the small lift-valve in one of the gates. The quoins were quite tight and the sill nearly so. The total amount of leakage was almost negligible.

Emergency Coffer-dam.—A feature of the work is the provision made, on the recommendation of Mr. T. E. Burrows, District Engineer, for the erection, in case of emergency, of a temporary coffer-dam outside the gates (*Figs. 4*), which can be easily put in

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position and pumped out, thus enabling any repairs to the gates or sill to be readily and cheaply effected. A groove, 1 foot 2 inches in depth and 4 inches in width, was cut in the rock bottom, 31 feet in front of the centres of the hollow quoins, across the whole width of the entrance, to receive the ends of 4-inch planks set vertically; these planks are to be supported above the bottom by horizontal walings, 12 inches by 6 inches, resting against vertical posts, 14 inches by 12 inches, let into holes, 14 inches in depth, cut in the rock bottom; the upper ends of the posts are to be braced off the retaining-walls at the sides of the dock entrance, *Figs. 4.* The channelling and cutting of holes in the rock was done before the removal of the coffer-dam. The side-walls of the dock were found to have good uniform strata of rock throughout a large part of their area, and this was trimmed to the true section; the upper layers at the front end and part of the remainder were so loose and cracked that it was decided to concrete them. The extreme outer end and the gate-recess walls were only in rock on their foundations and were built in concrete. The total amount of concrete used in these portions and in the sill and the drains inside was 376 cubic yards up to the end of December, 1901, and it is expected that 100 cubic yards to 150 cubic yards more will be required to complete the work.

The Paper is accompanied by a sheet of tracings, from which the Figures in the text have been prepared.

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(*Paper No. 3371.*)

"The Düsseldorf Navigation Congress, 1902; and Works visited by the Congress in Germany."

By LEVESON FRANCIS VERNON-HARCOURT, M.A., M. Inst. C.E.

An inaugural reception of the members was held at the Tonhalle, Düsseldorf, in the evening of 29 June, 1902, and the Ninth International Navigation Congress was formally opened the following morning by H.I.H. the Crown Prince of Germany, as Patron of the Congress. The sittings of the Congress were brought to a close on 4 July; but visits to works were arranged in the neighbourhood of Düsseldorf in the intervals between the meetings; and, after the close of the business, expeditions to inspect navigation works at a distance were undertaken, terminating on 8 July. The visits comprised the Rhine and its ports, between Königswinter and Ruhrort; the Elberfeld and Barmen Suspended Railway; the Dortmund-Ems Canal; the ports of Bremen and Bremerhaven, and the Weser estuary; the Elbe estuary up to Brunsbüttel; the Kaiser-Wilhelm Canal, and Kiel Harbour; the Elbe-Trave Canal; and the port of Hamburg. On the return of the Author from the Congress, which he attended as the delegate of the Institution, he was requested by the Secretary to write an account of the proceedings of the Congress; and he has, accordingly, prepared this Paper in compliance with the request thus made.

THE DÜSSELDORF NAVIGATION CONGRESS.

The Papers presented to the Congress were considered in two sections only, the first section dealing with Inland Navigation, and the second section with Maritime Navigation. Three questions were submitted for consideration in each section, namely: (1) "The Surmounting of Great Differences of Level," (2) "Ship Tolls," and (3) "Depreciation of Coal and Coke by Shipment," for the first; and (1) "Cost of Construction and Maintenance of

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Iron and Wooden Lock-Gates," (2) "Sea-Lighter Trade," and (3) "Dry Docks," for the second section, several Papers having been obtained from engineers of different countries on each question. For the first time, instead of a summary of each Paper being given by the writer, a synopsis of the principal points of the several Papers on each question was prepared and read out to the section, by a German engineer specially selected, and termed "General Reporter" for the particular question, together with his criticisms and conclusions, before the discussion of the question was commenced. On the termination of the discussion, the conclusions drawn up by the General Reporter were submitted to the section, and after criticism and any suggested amendments, were voted upon and passed. The conclusions thus arrived at, in each section, on the several questions selected for consideration, were read out successively at the final General Meeting of the Congress, in German, French, and English, and adopted.[1]

Conclusions approved by the Congress.—The conclusions adopted by the first section, on the three questions proposed for consideration, are as follows:—

First Question. (1) Locks still constitute the most simple and secure means for surmounting differences of level on canals. Side ponds enable the consumption of water in locking to be considerably reduced, without unduly increasing the time occupied in lockage. It is advisable to encourage investigations aiming at a still further reduction in the consumption.

(2) Where exceptional differences of level have to be surmounted in a short distance, double flights of locks provide a very practical method for canals having a large traffic, when a fairly abundant supply of water is available. If the supply of water is inadequate, vertical lifts provide a method which possesses the sanction of experience.

(3) Inclined planes, hitherto only applied to barges of small size, have formed the subject of ingenious proposals for vessels of large tonnage for inland navigation. The Congress expresses the earnest desire that a practical experiment, comprising the construction and working of one of these schemes, should be carried out as soon as possible.

Second Question. (1) The tolls for navigation on artificial waterways must not amount to such a sum as to frustrate the

[1] The reports of the discussions on the several questions in the two sections, as well as the speeches delivered at the two General Meetings of the Congress, and the conclusions passed at the closing General Meeting, have been recently printed and distributed as the Proceedings of the Congress.

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object aimed at by the navigable waterway, or cause it serious detriment, and thus put a stop to the economic function of the navigation.

(2) In the countries where the law or public opinion recognizes that the tolls for navigation on artificial waterways should not do more than cover the expenses of maintenance and working, together with the usual charge for interest and repayment of capital, it appears only reasonable, in fixing the tolls, to take into account also the indirect financial advantage accruing to the State from the increase in the taxable capabilities effected by the waterway. This should only be dispensed with in cases when political considerations necessitate the obtaining of a greater return from the waterway.

(3) The Congress is of opinion that the following reply should be given to the questions laid down in the programme.

The answer to the question whether it is possible to impose tolls for navigation on artificial waterways, adequate to cover the expenses of maintenance and working and to provide a reasonable interest on the capital cost of construction, depends upon a variety of circumstances. These mainly consist of the length and capacity of the waterway under consideration, the importance of the traffic on this waterway and of the railway rates, the system of collection and basis of the tolls for navigation, and the economic and political objects in respect of transport sought by the waterway.

Under certain circumstances it is possible, in establishing tolls for navigation on artificial waterways, to succeed both in defraying the expenses of maintenance and working, and in obtaining a reasonable interest on the capital expended in construction.

Third Question. In the case of friable coals, which tend to depreciate in value in the course of transportation, the existing installations, comprising wheel-barrows, loading-quays, coal-tips, and the combinations of these different contrivances, do not appear to afford entirely satisfactory results. The Congress, consequently, expresses the desire that the different associations or companies interested should offer prizes for competitive designs, with the object of ascertaining the improvements that should be introduced in order to effect a more satisfactory loading, transportation, unloading, or lightering of coal and coke.

It would be expedient to investigate the very diverse qualities of coal in the different coalfields.

The second section arrived at the following conclusions on the three questions submitted for the consideration of the members.

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First Question. (1) The Congress is of opinion that no definite conclusion can be arrived at as to whether the construction of lock-gates in wood or iron is preferable.

(2) This question depends upon technical and financial considerations, and is different in each case.

(3) In respect of gates of large size, iron is to be preferred, (*a*) because they can be made stronger and more stable with this material; (*b*) because metal gates can be moved more easily and quickly; (*c*) and, lastly, because their removal and renewal can be accomplished more quickly, and at a less cost, than in the case of wooden lock-gates.

Second Question. (1) The Congress is of opinion that the employment of sea-going lighters is of considerable interest to commerce and the working of seaports, and that their importance will probably still further increase. It is also of opinion that all special regulations liable to impede the circulation of lighters in the canals and seaports should be avoided.

(2) The size of the lighters should be proportioned to the dimensions of the canals. It seems expedient that the navigable waterways opening straight into the sea, should have a depth of 10 feet, and a corresponding width. The size of sea-going lighters is only limited by the power of the tugs.

(3) The North Sea and the Baltic, as well as the Mediterranean coasts are not the only spheres for the employment of lighters; but there has not hitherto been sufficient experience as to the utilisation of lighters for ocean navigation.

(4) The use of sea-going lighters could not replace the use of lighters on inland waterways.

Third Question. (1) In selecting a system for a ship-repairing establishment, the first point to be determined is whether the dockyard is to form part of the equipment of the port in the general interests of the shipping, or whether it is to be worked with a view to direct profits as an independent undertaking. In the former case, graving-docks are almost always preferable to all other systems, considering the simplicity, durability, and security which they afford. In the latter case, less costly arrangements may be more advantageous.

(2) For the repair of very large ships, graving-docks and floating dry-docks are the only systems really available. Neither system possesses such decided advantages over the other as to render its exclusive adoption expedient. In each case, the advantages and inconveniences of the two systems must be carefully weighed.

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(3) The following considerations specially determine the selection :—

(*a*) The capabilities required of the dock in respect of the rapidity, safety, and variety of the work to be carried out.

(*b*) The period allowed for its construction.

(*c*) The economy of the undertaking, which has often to be made subservient to the great advantages which the whole of the shipping derives from such a dock.

Communications sent in to the Congress.—In addition to the twenty-four Papers presented to Section I., and the fifteen Papers to Section II., which, together with the six General Reports, have been printed in German, French, and English, twenty-five Communications were sent in to Section I., and seventeen to Section II., on various subjects relating to inland and maritime navigation respectively, on which information was requested or appeared acceptable. These Communications, however, have been only printed in the language in which they were written. They were only considered after the close of the discussions on the regular questions, so far as time permitted; and no conclusions were formulated with regard to them; but they furnish valuable detailed particulars of the several works described.

The Lower Rhine and its Ports in Germany.

The Rhine, which is navigable up to Strassburg, and is the most important inland waterway in Germany, is an entirely open navigation, having been improved solely by regulation-works aided by dredging. This method of improvement has been rendered practicable by the large size of the river, draining a basin of 86,000 square miles, although reduced to 16,000 square miles at Strassburg, and by its fairly moderate fall of 412 feet in the 355⅓ miles between Strassburg and the Dutch frontier. This fall, however, is somewhat irregularly distributed; for although the fall is eventually reduced from 3·1 feet per mile at Strassburg to 0·63 foot per mile at the frontier, and the fall diminishes tolerably uniformly from Strassburg to 0·48 foot per mile at Oppenheim, a little above Mainz, it begins to increase again below, reaching 0·825 foot per mile above Bingen; whilst below Bingen, the fall through the rocky defile attains a fall of 2·51 feet per mile, which again decreases with some fluctuations to 1·32 foot per mile above Coblenz. Below Coblenz the fall augments again to 1·47 foot per mile, and subsequently drops by degrees to 0·91 foot per mile above Bonn; from Bonn to Cologne it is 1·23 foot, and from

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Cologne to Düsseldorf it is 0·89 foot per mile; whilst from Düsseldorf to the frontier, it decreases fairly regularly in stages, from 0·98 foot to 0·63 foot per mile,[1] Fig. 1, Plate 6.

Regulation-Works and Navigable Depth.—The Rhine between Mainz and the Dutch frontier has been systematically regulated in wide, shallow reaches, chiefly by projecting spurs or dykes, generally extending into the river from one bank, but occasionally from both banks where the conditions are unfavourable, as for example in a wide reach between two bends; and sometimes longitudinal dykes have been resorted to, connected usually with the river-bank by cross dykes.[2] These dykes consist chiefly of earthwork mounds, protected on the face by rubble or pitching, with a rubble mound on the exposed toe; and occasionally fascines are employed in conjunction with stone, or a rubble mound alone. These regulation-works have, for the greater part, been gradually carried out during the latter half of the nineteenth century; and two examples of somewhat recent and extensive regulation-works, constructed about half-way between Biebrich and Bingen, and just above Königswinter respectively, are illustrated in Figs. 2 and 3, Plate 6. These works, in conjunction with dredging where necessary, have provided a navigable depth at the ordinary low stage of the river, of 10 feet from the Dutch frontier up to Cologne, and 8½ feet between Cologne and Caub at the base of the steep slope below Bingen; above which point the available depth at average low water is reduced to 6½ feet, which is maintained up to Philippsburg, about 22½ miles above Mannheim.

Although the course of the river was considerably rectified in places between Mannheim and Strassburg in the last century, a depth of 6½ feet at the low stage has not hitherto been secured. Regulation-works, however, have been designed for deepening the river between Sondernheim, about 5 miles above Philippsburg, and Strassburg, which were to be commenced in 1902, and are expected to occupy 14 years in construction, by means of which it is anticipated that an available depth of 6½ feet will be attained at Strassburg, increasing to 8½ feet at Maxau, about 12 miles above Sondernheim.[3]

Ports on the Lower Rhine.—The larger towns on the banks of the Rhine have been furnished with ports, comprising generally quays

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[1] "Der Rhein von Strassburg bis zur holländischen Grenze," E. Beyerhaus, Plate 1.

[2] *Ibid*, pp. 10 to 80, and Plates 2 to 5.

[3] *Ibid*, pp. 5 to 9, and Plate 1.

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along the river-bank, and one or more basins formed along the foreshore of the river, or excavated in the adjacent low-lying land. These basins, regulated in number and dimensions according to the importance of the port or its prospects of traffic, are surrounded by quays, which are equipped with cranes, sidings, and sheds or warehouses; and the basins, besides serving with the river quays for the unloading and loading of vessels, provide a refuge for the vessels in the winter from floods and floating ice coming down the river, for which purpose their open entrances are always placed at the downstream end.

The upper ports of Mannheim, Gustavsburg, and Mainz, were described by the Author after his visit to them in 1888[1]; and the only extensions carried out in the interval consist of a lock connecting the River Neckar, near its mouth, with the basin formed by the old course of the Rhine, and an increased equipment of the quays round the other basins at Mannheim, and the addition of a fifth basin at Gustavsburg.

The most important ports on the lower part of the Rhine in Germany, in respect of length of quays and traffic, are Cologne, Düsseldorf, Duisburg, and Ruhrort; and the basins provided for these ports, in addition to quays along the river-bank, are shown in Figs. 4, 5, and 9,[2] Plate 6. The series of basins at Düsseldorf was constructed in 1890–96, and the single basin at Cologne in 1891–98; but although the area of the Düsseldorf basins amounts to nearly four times the area of the Cologne basin, the total length of quays at the port of Cologne is nearly one fifth greater than that of the quays at Düsseldorf. The addition of these basins has been accompanied by a distinct increase in the traffic; for the exports and imports at Cologne amounted to 523,600 tons in 1890, 624,600 tons in 1895, and 874,500 tons in 1900; and at Düsseldorf, 241,000 tons, 335,600 tons, and 620,300 tons respectively. The Cologne basin, which with its equipment cost about £750,000, has been of great advantage as a refuge for vessels, having been closely packed with them during the drifting down of the ice in the winter of 1899–1900; and a Customs port has been provided along 1,673 feet of the river-side of the quay enclosing the basin, Fig. 4, Plate 6. Düsseldorf, however, has been more amply furnished with separate conveniences for trade; a Customs basin, a

[1] Minutes of Proceedings Inst. C.E., vol. xcvi. p. 198, and Plate 6, Figs. 7 to 10.

[2] The basins at the ports of Duisburg and Ruhrort are so much more extensive than those at the ports of Cologne and Düsseldorf, that it has been necessary to draw them to a smaller scale.

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petroleum basin, and a basin constituting a free port, as well as two other inner basins, having been provided, at a cost of about £500,000, Fig. 5, Plate 6. Quays also have been constructed in 1899–1902, along the river-bank below the basins and in front of the town, as shown in cross section in Fig. 6, Plate 6; and the construction of the quay-walls of the basins on land, and in the river-bed respectively, is shown in Figs. 7 and 8, Plate 6.

The two adjacent ports of Duisburg and Ruhrort, separated only by the River Ruhr, which flows into the Rhine between them, have together long held the leading position amongst the Rhine ports of Germany, Fig. 9, Plate 6; for although the port of Mannheim has kept ahead of Duisburg in traffic, it has always remained considerably behind the port of Ruhrort, in spite of its favourable position at the head of a large inland waterway, *Fig. 12.* The commanding position of Ruhrort is due to its very large export of coal, which, together with coke, constituted in 1901 as much as 72 per cent. of the whole of the exports and imports; whilst the imports, which are rather less than one-fourth of the exports, consist mainly of iron ore, pig-iron, and grain. The export of coal also constitutes rather more than two-thirds of the tonnage of the port of Duisburg; whilst its imports comprise chiefly iron ore, grain, and wood. To provide for this trade, basins and quays have been constructed at both these ports, with a water-area and length of quays of 138½ acres and 9½ miles at Ruhrort, and 105 acres and 8 miles at Duisburg, Fig. 9, Plate 6; and both ports are well supplied with coal-tips, sidings, and other appliances. Large extensions, moreover, have been recently designed for both ports, to cope with the rapidly increasing traffic, which are indicated by dotted lines on the plan; and the new basins at Ruhrort are to be given a depth of 2 feet to 2 feet 8 inches more than the existing basins, as well as a greater width.

The accommodation provided at the principal ports on the Rhine above Duisburg and Ruhrort, in respect of water-area and length of quays, is as follows: at Mannheim, 410 acres of water and 21¾ miles of quays; at Ludwigshafen, 33 acres and 6½ miles; at Gustavsburg, 24½ acres and 1¾ mile; at Mainz, 166½ acres and 4 miles; at Frankfort-on-the-Main, which is classed with the Rhine ports,[1] 10½ acres and 4¾ miles; at Cologne, 14 acres and 7⅕ miles; and at Düsseldorf, 54⅔ acres of water-area of basins and 5⅝ miles of quays.[2] On comparing these provisions with the traffic of

[1] Minutes of Proceedings Inst. C.E., vol. xcvi. p. 194, and Plate 6, Fig. 6.

[2] "Der Rhein von Strassburg bis zur holländischen Grenze," E. Beyerhaus, pp. 82 to 84.

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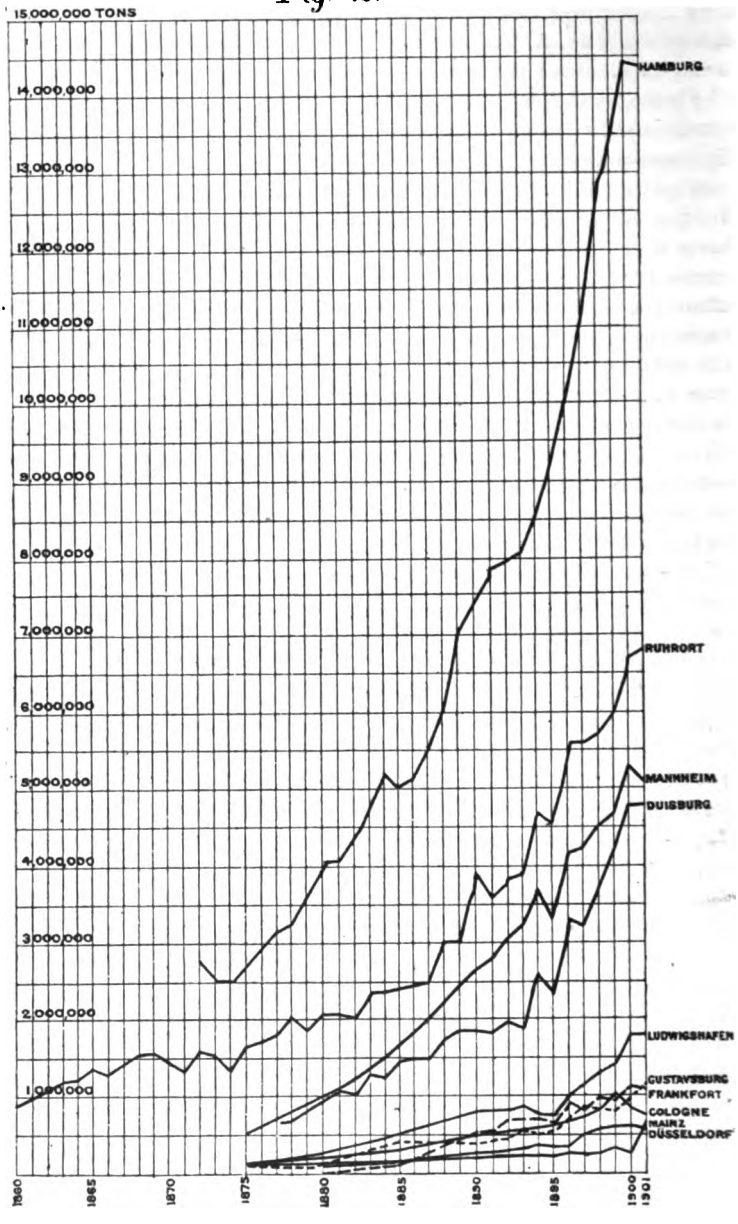
Fig. 12.



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the respective ports, it is evident that in some cases they have been determined by the local conditions rather than by the requirements of the port, as specially exemplified by Mannheim, where a bend cut off from the Rhine has been utilized as a basin.

Traffic on the Rhine and at its Ports.—The traffic along the Rhine is conducted by sea-going steamboats, by large barges towed in trains by tugs, and by sailing vessels. The smallest sea-going steamboat navigating the Rhine has a length of 117 feet, a beam of 20½ feet, a draught of 11¾ feet, and a carrying capacity of 342 tons; and the largest is 233 feet long, 33⅓ feet beam, and 14 feet draught, and can carry 1,770 tons. The tugs constitute two-thirds of all the steamboats navigating the Rhine; and the most powerful ones are between 1,250 HP. and 1,400 HP. About half of the Rhine fleet of barges and sailing vessels have been built of wood; but the tonnage of the iron vessels amounts to four times that of the wooden vessels, as the larger vessels have been built of iron, and the use of wood is being discontinued. The flat-bottomed, average-sized barges towed on the Rhine are 265 feet in length, 33 feet beam, 10 feet in depth of hull, and of 1,200 tons capacity; whilst the larger barges reach a length of 289 feet, a breadth of 39½ feet, a depth of 8½ feet, and a capacity of 2,290 tons; and the largest barge on the Rhine is 328 feet in length, 39½ feet beam, 9 feet in depth, and of 3,241 tons capacity.

The growth of the traffic at some of the principal Rhine ports of Germany, up to the end of 1901, is indicated by the accompanying diagram, *Fig. 12*, from which it appears that the progress has been fairly continuous, and in some cases rapid in recent years.

Bridges recently built across the Lower Rhine.—Two road-bridges have recently been constructed over the Rhine, namely, at Bonn in 1896–98, and at Düsseldorf in 1896–99. Both bridges are similar in type, (Figs. 10 and 11, Plate 6) for their large openings across the navigable channel are spanned by metal arches, from which the roadway is suspended; and the thrust of the large arches is compensated for by smaller, low arches at the sides, supporting the roadway above them.[1] The bridge at Bonn is the more graceful, on account of its symmetrical form, with its single large central span of 614¼ feet, flanked by a side span at each end of 307 feet, and its double, slender, cone-capped towers on each pier, Fig. 10, Plate 6. As the river is considerably wider down at Düsseldorf, two large spans of 594½ feet are provided over the navigable

[1] *Zeitschrift des Vereines deutscher Ingenieure*, Berlin, 1899, vol. xliii. pp. 310, and 318, and Plate 8 in text; and "Der Rhein von Strassburg bis zur holländischen Grenze," pp. 30 and 51.

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waterway, with one side span of 198 feet over the right bank on the Düsseldorf side, and three spans of 208 feet, 187 feet, and 164 feet, to the opposite bank across the foreshore, Fig. 11, Plate 6. The superstructures on the piers of the main spans are somewhat more massive than those at Bonn, and a colossal lion, the cognizance of Düsseldorf, crowns the central pier; whilst the two main arches present a light appearance, similar to the central span at Bonn. The two bridges, indeed, besides affording interesting examples of the arch principle applied to large spans, form picturesque features in the flat country surrounding them.

Elberfeld and Barmen Suspended Railway.[1]

About 15 miles from Düsseldorf are situated the two very important manufacturing towns of Elberfeld and Barmen on the River Wupper, a small tributary of the Rhine, which have been extended along the river so as now to form practically a continuous line of buildings on both sides of the rapid stream, between 5 and 6 miles long. The main line of railway from Düsseldorf and from Cologne traverses these towns on the southern side of the Wupper, and another line skirts the northern suburbs; whilst an electric tramway passes along the principal line of streets from end to end. These facilities, however, proved insufficient to meet the requirements of a populous, busy, and extended district; and the electric tramway, indeed, which under ordinary conditions provides the natural, cheap, and fairly quick method of transit to any part in a straggling industrial centre, is hampered in its passage through Elberfeld and Barmen by frequent obstructions in the narrow, tortuous streets. Accordingly, a novel method of locomotion, by carriages suspended from two pairs of tandem double-flanged wheels running on an overhead mono-rail, and worked by electric motors, has been devised, so as to be quite independent of the streets, and thus meet the special necessities of the locality, *Figs. 13* to *16*.

Course of the Railway.—The railway starts at Vohwinkel, a town to the west of Elberfeld, and after skirting a suburb, Sonnborn, it proceeds right through the centre of Elberfeld and Barmen, having a total length of 8¼ miles. For the first two miles from the Vohwinkel terminus, the railway passes along over the lines of streets and roads through Vohwinkel, and on to Sonnborn, after

[1] Minutes of Proceedings Inst. C.E., vol. cxlii. p. 452.

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traversing which, it turns off over the River Wupper, whose windings it follows for the remaining 6¼ miles of its course. By this arrangement, the cost of the purchase of property in the closely-built towns of Elberfeld and Barmen was to a great extent saved, and the inconvenience of supports for the overhead line in narrow, crowded thoroughfares was avoided; whilst the central part of these two long, continuous towns has been traversed from end to end, without in the least interfering with the existing means of communication.[1]

In addition to the two terminal stations of Vohwinkel and Barmen, there are eighteen intermediate stations, 350 yards to 5 furlongs apart, and giving an average interval of 3½ furlongs between the stations, which appears ample, when combined with a frequent train-service, for the proper accommodation of the towns traversed, considering that the tramway-cars in German towns only stop at definite points.

Gradients, Curves, and Sidings of the Railway.—The line follows approximately the variations in the levels of the land and river over which it passes, at an elevation of not less than 26 feet, so that the bottom of the suspended carriages, which is 11¼ feet below the rail-level, may leave a headway of 14¾ feet underneath. The line falls rapidly from Vohwinkel towards Sonnborn; and on reaching the River Wupper, and proceeding over it upstream, the line rises gradually, with the rise of the river-bed, to Barmen, with such modifications as are necessary to provide the requisite headway over the roadways of the bridges crossing the river. The steepest gradient is 1 in 22·2, close to the Vohwinkel terminus. The sharpest curves on the regular line have a radius of 4½ chains, with the exception of a short curve of 1½ chain radius on the arrival-line at the entrance to Vohwinkel terminus; and the gradients and curves are so distributed that the speed of the trains, of 31 miles an hour, between the stations need never be slackened. The two lines, however, are joined at each terminus by a loop-line of 29½ feet radius, so as to form a closed circuit, along which the two to four carriages constituting the trains, always run in the same position, *Fig. 17*; whilst curves having a minimum radius of 26¼ feet are introduced at the siding.

The sidings arranged under a shed at Vohwinkel, serve for putting away the trains under shelter at night, having eight lines, six of

[1] In response to an inquiry, Dr. Lentz, Oberbürgermeister of Barmen, sent the Author three pamphlets giving descriptions and illustrations of the Elberfeld and Barmen Railway.

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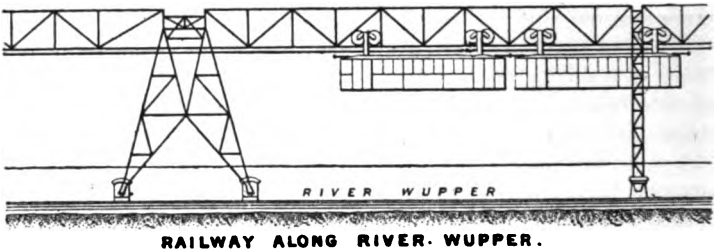
which are connected at their ends by curves, to which access from the main lines can be successively obtained by the pivoting switches

Fig. 13.

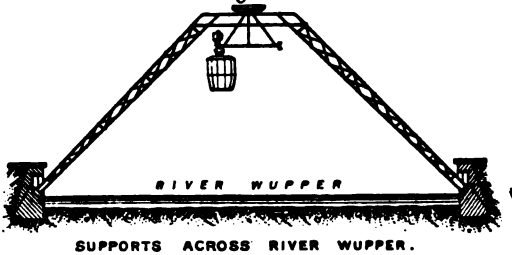


RAILWAY ALONG RIVER WUPPER.

Fig. 15.

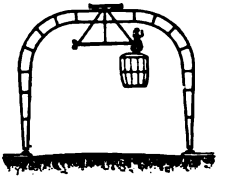
RAILWAY ALONG STREET.

Fig. 14.



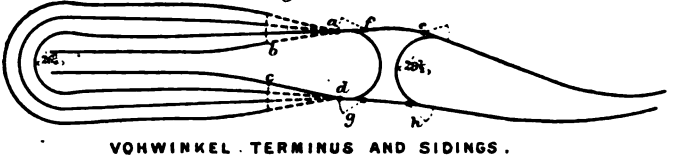
SUPPORTS ACROSS RIVER WUPPER.

Fig. 16.



SUPPORTS ACROSS STREET

Fig. 17.



VOHWINKEL TERMINUS AND SIDINGS.

ab, *cd*, *Fig. 17.* Two short side lines connect the two main lines with these switches, on which the trains are led to the sidings at night, and from them to the main lines in the morning, by aid of

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the two pairs of switches *ef* and *gh*; and a reverse loop in connection with the pivoting switches facilitates the shunting of the trains in the sidings. The usual course is for the trains to enter the sidings by means of the switches *e* and *f*, and to leave them by *g* and *h*; but the shunting in and out can be effected through either pair of switches in case of necessity.[1] Sidings have also been provided at the station in Elberfeld nearest to Vohwinkel, to avoid having to run all the trains through the less populous suburbs and country districts between Elberfeld and Vohwinkel. These sidings diverge slightly from the outside of each main line, and dipping down sufficiently to give clearance under the main lines for the tandem wheels, are connected about halfway along their length by a loop-line, so that the trains can be either transferred directly from one main line to the other, or be shunted for a time into one of the two sidings till required.

Construction of the Railway.—In passing along over the streets and roads between Vohwinkel and the River Wupper, the railway is carried by a longitudinal girder supported by iron standards erected in pairs at intervals along the curbs of the pavements in streets, or at the sides of the roads, and connected together at the top across the roadway, as in other elevated railways, *Figs. 15* and *16*. In this case, however, it was necessary that the bottom flange of the girder should project sufficiently on each side to carry the rail of each line on its outer edge, and leave ample clearance for the suspended carriages to pass one another below, and also adequately underneath the transverse supports to provide the requisite headway for the tandem wheels running on each rail, *Fig. 16*.

It was originally intended to carry the portion of the railway following the River Wupper, on standards placed in the river-bed; but owing to the unprecedented height of a flood which occurred just before the work was commenced, it was deemed essential to found the supports beyond the river-bed. This has led to the adoption of sloping, braced, iron supports projecting over the river, founded on the banks, or in side walls or buildings bordering the stream, each pair of supports being connected at the top by a short, horizontal, transverse girder which bears the longitudinal girder carrying the railway, *Figs. 13* and *14*. The obligation

[1] *Zeitschrift des Vereines deutscher Ingenieure*, 1900, vol. xliv. pp. 1,373 to 1,404; and reprints of "Die Schwebebahn Barmen-Elberfeld-Vohwinkel" from *Elektrotechnischen Zeitschrift*, 1901; "Le Chemin de Fer Suspendu" from *Le Génie Civil*, 1900; and "The Langen Mono-rail Suspended Railway at Elberfeld-Barmen," from *Engineering*, 1900.

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thus imposed, of making the supporting framework span the river, which has a width varying between 66 feet and 115 feet in flowing through the towns, has increased considerably the cost of the railway.

The supports, both along the roads and stretching over the river, are made stronger, and rigidly fixed at their base, at intervals of about 220 yards to 330 yards; and an expansion joint is provided in the longitudinal girder midway between them, *Figs. 13* and *15*. The lighter intermediate supports, placed about 33 yards apart, are made to rest at their base on ball-and-socket bearings, so as to be free to oscillate backwards and forwards, in the direction of the line, with the contraction and expansion of the longitudinal girder resulting from changes in temperature. The erection of the portion of the elevated railway over the River Wupper, was partly effected by means of scaffolding resting on the river-bed, and partly by building out from the completed work.

The railway was commenced in 1898; and the Elberfeld section of the line was opened for traffic in the autumn of 1900, and up to the Vohwinkel terminus in the following winter. The extension through Barmen, however, was still in course of construction in the summer of 1902. The cost of the works, including the stations, has been reckoned at between £36,000 and £40,000 per mile, as much as 15,000 tons of iron having been employed in their construction; but the provision of a complete working equipment, so as to enable trains of two carriages to be run at intervals of only three minutes, at a speed of 31 miles an hour, would, it is estimated, raise the total cost to £56,000 per mile.[1]

Description of the Carriages and Working Arrangements.—A train on the railway is commonly composed of two carriages; but four carriages can be run in a train if required. Each carriage is 37½ feet long, 7 feet wide, and 8¾ feet high over all; it is constructed of mild steel, and lined inside with wood; and with its two pairs of tandem bogie wheels, its motors, its suspension gear and other machinery, and its full complement of fifty passengers, it weighs 14 tons, *Figs. 18* and *19*. The two pairs of double-flanged tandem wheels in bogie frames, which convey the carriage and run on a flat-bottomed mono-rail, are placed 26¼ feet apart, centre to centre; each wheel is 35½ inches in diameter; and each pair of wheels is provided with an electric motor of 36 HP. at 500 volts, *Fig. 19*. The bogie frame of one pair of wheels, with the motor in front of it, is shown in *Fig. 18*, and also its position in relation

[1] Zeitschrift des Vereines deutscher Ingenieure, 1900, vol. xliv. p. 131.

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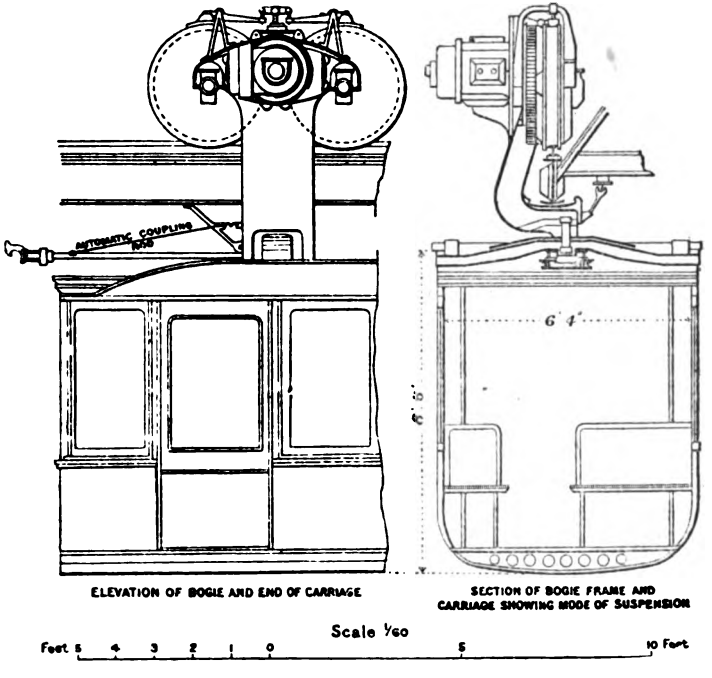
to the carriage suspended from it, of which a partial elevation is given; and the mode of suspension of the carriage from the bogie frame is indicated in *Fig.19*, with a cross section of the carriage.

The wheels, bogie frames, and suspended carriages are free to oscillate on the round-headed mono-rail as a centre, to the extent of 15° on either side of the vertical, in going round curves, or when exposed to a high wind, which latter force, however, has been found to have little effect on the carriages. A vertical piece

Fig: 18. *Fig: 19.*



extends below the bottom of the hook of the bogie frame, terminated by a channel-bar, through which the transverse beam, stretching across the roof of the carriage and bearing its weight, passes and is supported; and in this part of the bogie frame the vertical steel pivot of the bogie is placed, passing through the centre of the transverse beam, which enables the wheels and the carriage to assume different relative positions in going round curves, *Fig. 19.* A space slightly exceeding ¼ inch, is left between the curved bottom of the rail-bearer and the upper surface

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of the horizontal piece of the hook-like portion of the bogie frame, so as to allow of the oscillation of the bogie frame, and consequently of the carriage; whilst the amount of play left under the rail-bearer is small enough to prevent the possibility of the wheels, with flanges projecting 1½ inch, to leave the rail. The bogie frame, moreover, is so designed that in the event of the fracture of a wheel or an axle, the frame would merely settle down upon the rail; whilst the breaking of the pivot of a bogie would only cause the transverse supporting frame of the carriage to drop upon the channel-bar at the base of the bogie frame, *Fig. 19*.

The electric current is obtained by means of a sliding shoe projecting from the extremity of the hook-shaped part of the bogie frame, and pressed against the conductor by a spiral spring, as shown in *Fig. 19*. The iron rail forming the conductor is carried along the underside of the bottom member of the longitudinal girder; and it is supplied with electricity from the central power-station established alongside the railway in Elberfeld. Electric incandescent lamps also are used for lighting the carriages.

Each carriage is furnished with a Westinghouse brake, the compressed air for which is supplied at the termini at a pressure of 115 lbs. per square inch, and stored in iron pipes, 36 feet in length and 4 inches in diameter, which are placed under the floor of the carriage, and assist in supporting it, *Fig. 19*. Electric brakes can also be applied by putting the motors out of circuit, or by reversing the current. An automatic block system has been established, which is worked electrically by the trains themselves, the intervals between the several stations constituting the blocks, and enabling trains to be despatched every two minutes. A train on leaving a station when the signal at the station is lowered, puts up this signal to danger on passing it, and lowers the signal at the preceding station on clearing the block. A speed of 18⅔ miles to 22½ miles per hour, including stoppages, is attained by the trains, as the full speed of 31 miles an hour can be reached in 15 seconds after starting; and the travelling is smooth and easy, in spite of the succession of curves necessitated by the winding course of the River Wupper. The automatic coupling together of the carriages of a train is effected at the level of their roofs, *Fig. 18*.

Remarks on the Suspended Railway.—The conditions at Elberfeld and Barmen are somewhat peculiar, for these towns are situated in a narrow valley, sloping rather rapidly up on either side, so that the business quarters have had to be extended along the lower part of the valley; and the manufactories to a great extent border the river, into which they discharge their refuse. The busy

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portions of the town are, accordingly, long and narrow, and the traffic consequently congested; whilst the narrowness of the flat ground precluded the extension of convenient means of communication at the sides. Thus the river offered the only open line for traversing the towns centrally, and with a fairly level railway; and as the river is only used by the manufactories, there was no objection to following its course where these buildings border it on either side. In passing close to residential property along the streets of Vohwinkel, however, and near valuable houses along the river in the upper part of Barmen, the railway is open to the objections of elevated lines through towns, and must have occasioned a serious depreciation in the adjacent properties. It is, however, anticipated that the railway will develop the suburbs and country districts between Elberfeld and Vohwinkel; and Barmen, also, will largely benefit by the improved means of communication with Elberfeld.

Several advantages have been claimed for this suspended system over ordinary elevated railways, with regard to some of which extended experience alone can decide. Undoubtedly, the lower level of the platforms of the stations, with suspended carriages, is an advantage for the passengers; but it must not be overlooked that the system, at the same time, entails higher supports to obtain the necessary headway, than with overhead carriages. The lightness of the rolling-stock in relation to the number of passengers carried, is only due to the system to the extent that two pairs of wheels take the place of four pairs; whilst, with fifty passengers in a carriage, seats are only provided for thirty. The chief merits of the system unquestionably are the ease and quietness of the motion, and the great facility tandem wheels on a single rail, similarly to bicycles, afford for passing rapidly round sharp curves. Moreover, the suspension system dispenses with the use of guide-rails at the sides, which constitute a necessary adjunct of the mono-rail lines on trestles with pannier carriages.

Starting near the suspended railway in the centre of Barmen, a ladder-rack railway,[1] worked electrically from an overhead wire, ascends the southern slope of the valley to a height known as the Barmen Wald. The railway commences the ascent by going up a very steep street; and then, diverging from the road, it climbs to the top along a special track, terminating near the Tolle Thurm, a revolving tower from which a fine view of the surrounding

[1] Minutes of Proceedings Inst. C.E., vol. cxlix. p. 370.

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neighbourhood and Rhine valley is obtained. The railway, nearly a mile in length, is ascended in about a quarter of an hour.

Dortmund-Ems Canal.

Extension of German Waterways.—The Dortmund-Ems Canal, connecting Dortmund and Herne in Westphalia with the port of Emden at the mouth of the River Ems, opening into the North Sea, forms only the first completed portion of a scheme for uniting the rivers of Germany by large waterways, so as to fully develop and extend inland navigation in the interests of commerce and the general prosperity of the country. Thus it is proposed to join the Dortmund-Ems Canal with the Rhine by a short canal from Herne, and to construct a canal starting from the Dortmund-Ems Canal at Bevergern, crossing the canalized Weser near Minden, and terminating by a junction with the Elbe near Magdeburg, thereby connecting the Rhine with the canalized Ems, the Weser, and the Elbe, as shown by dotted lines in Fig. 24, Plate 7. Moreover, the scheme includes the improvement of the waterways between Berlin and the Oder, the Oder itself, and the waterway connecting the Oder with the Vistula, so as to provide a continuous chain of waterways between the Rhine and the Vistula, connected with the intervening rivers flowing northwards, and extending across Germany from west to east, Figs. 24 and 25, Plate 7.

Object and Dimensions of the Dortmund-Ems Canal.—A short description of the Dortmund-Ems Canal was given, about a year before its opening, in a Paper on "River Regulation Works, and Harbour and Canal Construction in Germany,"[1] by Messrs. Franzius and de Thierry; and a more detailed account of the works, with illustrations, was presented in 1901 to Section II. of the Glasgow Engineering Congress.[2] It is, accordingly, proposed merely to give a few particulars, and such supplementary information and illustrations as may assist in further elucidating the subject.

Besides forming an important section of the contemplated network of large waterways in Germany, the Dortmund-Ems Canal has been constructed with the object of increasing the means of communication of the numerous collieries and ironworks in the neighbourhood of Dortmund and Herne, and affording them direct access by water to the sea, so as to enable them to compete under

[1] Minutes of Proceedings Inst. C.E., vol. cxxxv. p. 248.

[2] International Engineering Congress, Glasgow, 1901, Section II., Waterways and Maritime Works, Proceedings, p. 2.

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more favourable conditions with foreign trade. The works, which were authorised in 1886, were commenced in 1893, and completed in 1899.

The total length of the waterway between Dortmund and Emden, is 168 miles; and the branch to Herne is nearly 7 miles in length, which it is proposed eventually to extend to the Rhine at Ruhrort. The canalized, regulated, and open Ems occupies about 58 miles of the length, the remainder constituting the canal proper, including about 7 miles of lateral canal in place of the exposed lowest portion of the River Ems. The canalized Ems, and the canal above it, rise by seventeen locks to the long reach, 184 feet above mean sea-level, in which the port of Münster is situated, and which extends to Herne, a distance of 41⅔ miles; whilst the summit reach leading to Dortmund, 46 feet higher and 9½ miles long, is attained by means of a lift at Henrichenburg. The lower reach adjoining the long reach, to which access is obtained by a lock surmounting the difference of level of 20½ feet, has had its level so adjusted in designing the canal, that the proposed canal to the Elbe, which is to start from this reach, will be able to be constructed at the same level as far as Hanover, forming a single reach 130½ miles in length without the intervention of a lock, Figs. 24 and 25, Plate 7. This great available length of level reach is evidently due to the course of the proposed canal running from east to west, at right angles to the general slope of the country falling towards the north, as indicated by the flow of the rivers from south to north.

The canal has a depth of 8½ feet and a bottom width of 59 feet, which are the standard dimensions determined upon for the future extensions of waterways in Germany. The locks in the upper part of the canal have an available length of 220 feet, a width of 28½ feet, and a depth of 10 feet on the sill, accommodating a single barge; whilst the locks of the three lowest reaches of the canal, and in the canalized Ems, are 541½ feet long and 33 feet wide, so as to be able to receive two barges with their tug. The ordinary barges navigating the canal can carry 400 tons and 600 tons of cargo; but special barges have been built of the largest dimensions which the canal can admit, 220 feet long, 27 feet beam, and 6 feet 7 inches draught, carrying 950 tons. Sea-going lighters also, 197 feet long, 26¼ feet beam, and carrying 1,000 tons of cargo, with a draught of 8½ feet, coming from Bremen, Hamburg, and Baltic ports, enter the canal after reducing their draught to 6 feet 7 inches by the removal of 200 tons to 300 tons of their cargo.

Henrichenburg Floating Lift.—The canal-lift constructed for sur-

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mounting the rise of 46 feet from the long reach leading to Herne up to the special reach provided for Dortmund, differs from the previous hydraulic canal-lifts, with two counterbalanced troughs each supported by a central ram, at Anderton,[1] Les Fontinettes,[2] and La Louvière,[3] in having only a single trough supported on a series of floats immersed in wells, and wholly raised or lowered by drawing out or letting in a small amount of water, *Figs. 20* and *21*. The trough, moreover, at Henrichenburg has had to be made 230 feet long and 28½ feet wide, with 8½ feet depth of water, in order to admit the largest barges, of 950 tons, navigating the canal, much larger than the troughs of previous canal-lifts; for the troughs at Anderton are 75 feet by 15½ feet, with 5 feet depth of water, for 100-ton barges; at Les Fontinettes, 129½ feet by 18⅜ feet, with 6 feet 7 inches depth of water, for 300-ton barges; and at La Louvière, 141 feet by 19 feet, with 7 feet 10½ inches depth of water, for 400-ton barges. The trough is hung in a cradle borne by five lattice-work supports standing on five cylindrical steel-plate floats, 32¼ feet in height and 27¼ feet in diameter, floating in five wells full of water, and maintaining the whole moving load of 3,000 tons in perfect equilibrium, *Figs. 20* and *21*. The motion is controlled by four screw-spindles placed on each side of the trough towards each end, turned simultaneously by horizontal shafting connected with an electric motor, which stop the trough in its ascent slightly before its water-level attains the water-level of the upper reach, and similarly in its descent, so that water may be readily admitted and let out respectively, as the motion is effected entirely by the increased or diminished weight of water in the trough, reversing the equilibrium of the floats, and making them fall or rise in the wells. The pairs of lifting gates at each end of the trough, closing the end of the trough and of the reach, slide on free rollers, and are raised by the electric motor for admitting or letting out a barge. The lift appears to work quite satisfactorily, the actual lift being effected in 2½ minutes, as for a very similar height at Anderton and La Louvière; but the transference of a barge from the lower to the upper reach, and of another barge from the upper reach to the lower, occupies 25 minutes on the average. The cost of the lift, amounting to £130,000 for barges of 950 tons capacity, compares

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[1] Minutes of Proceedings Inst. C.E, vol. xlv. p. 107, and Plate 2.

[2] *Ibid*, vol. xcvi. p. 182; and "Civil Engineering as applied in Construction," p. 397.

[3] Minutes of Proceedings Inst. C.E., vol. xcvi. p. 184, and Plate 6, Fig. 1.

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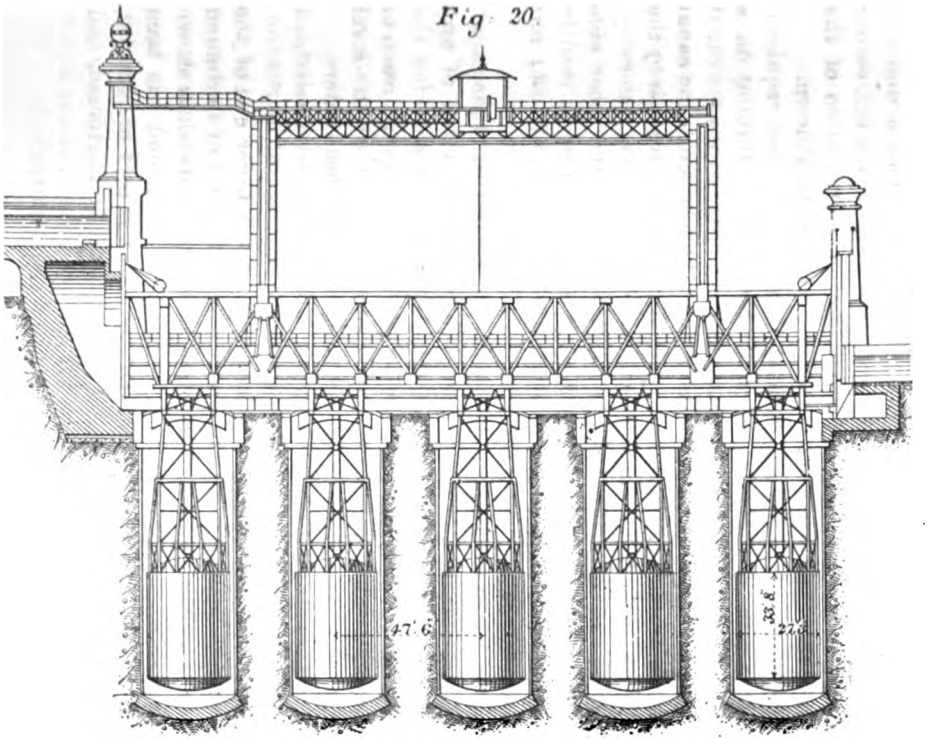
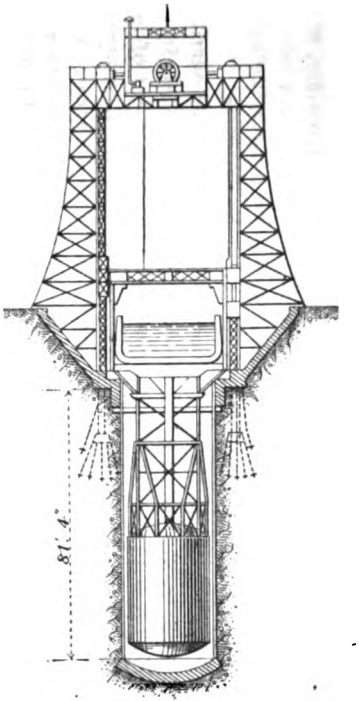
Fig. 20.



ELEVATION OF CANAL-LIFT SHOWING SUPPORTS AND FLOATS IN WELLS.

Fig. 21.



SECTIONAL ELEVATION OF CANAL-LIFT SHOWING SCREW SPINDLE AND FLOAT IN WELL.

Scale.

Feet 50 0 50 100 Feet.

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fairly well with the lift at Les Fontinettes, costing about £68,000 for barges of 300 tons, and with the lift at La Louvière, which cost £56,200, for barges of 400 tons; although the single trough at Henrichenburg affords less accommodation for a large traffic than the two counterbalancing troughs of the hydraulic lifts.

The canal-lift at Henrichenburg possesses the same merits as the earlier lifts, of effecting a considerable saving, both in time and in the expenditure of water, as compared with a flight of locks. The lift, however, in this case appears to have been constructed as an experiment of a canal-lift of much larger dimensions than previously, on a novel principle, rather than as the system best suited to the conditions; for it has been very definitely stated that, in the event of the traffic with Dortmund necessitating in the future more accommodation than the lift can afford, a flight of locks would be constructed in preference to a second lift, owing apparently to the fear that the considerable complication of the working parts renders the lift specially liable to breakdown.

Stop-Gates.—The canal is divided into sections, when required, by stop-gates at intervals, of novel construction, turning on a horizontal axis in the side walls, so as to be raised above the canal and leave the requisite headway of about 14 feet across the canal under normal conditions, and capable of being lowered into the water so as to form a watertight barrier across the waterway, *Figs. 22* and *23*. The gate is counterpoised on the other side of the axis in each side wall, *Fig. 23*, so that it can be readily lowered or raised by one man by means of a winch, *Fig. 22*; but the process occupies several minutes.

The object of the stop-gates is to isolate any section of the canal, lying between two of them, from the rest, in the event of any accident, or for repairs. They are also useful for checking the waves raised by high winds blowing along a long, straight reach of the canal; and they, moreover, serve for regulating the water-level in the canal during heavy rains and the influx of flood-waters.

Traffic on the Dortmund-Ems Canal.—Ports have been constructed for the accommodation of shipping at the terminus at Dortmund, and also at Münster, which is situated near the lower end of the long reach leading to Herne; and a plan of the port of Dortmund is given in Fig. 26, Plate 7, with proposed future extensions shown in dotted lines. The trade of the port of Dortmund has been somewhat greater up to the present than at the port of Münster, having commenced with 61,000 tons in 1898 at Dortmund, and reaching 158,000 tons in 1901; whereas at Münster, it was 38,000 tons in 1899, and amounted to 125,000 tons in 1901.

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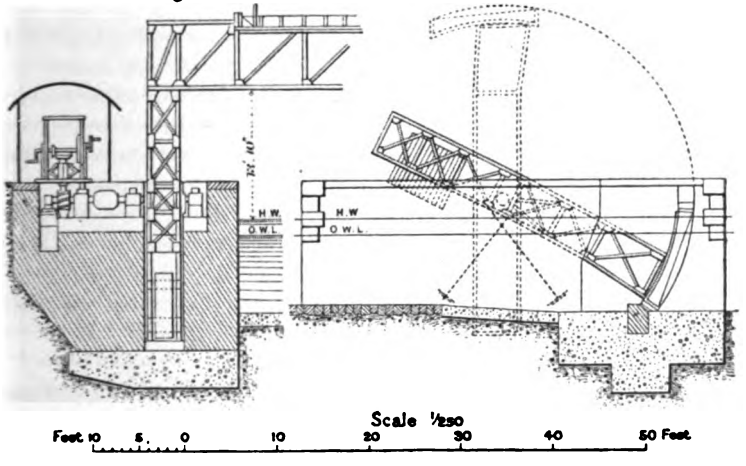
The imports on the canal, consisting mainly of timber, corn, and ores, have increased more rapidly in the first four years of the traffic than the exports, which comprise chiefly iron and coal. Thus the imports increased from 55,000 tons in 1898, before the works were quite finished, to 428,000 tons in 1901; whilst the exports rose from 64,000 tons in 1898 to 253,000 tons in 1901, making together a total rise from 119,000 tons in 1898 up to 681,000 tons in 1901. The actual traffic, moreover, reckoned in ton-miles, exhibited similarly a more rapid growth in the imports than in the exports on the canal, and a much greater proportionate total increase in the first four years of working, the total traffic having risen from 2,510,000 ton-miles in 1898 to 11,000,000 ton-miles in 1899, 31,800,000 ton-miles in 1900, and 50,150,000 ton-miles in 1901. It is, however, too early at present to form an estimate of what the traffic on the canal may amount to in the future, especially as extensions of the port of Emden, and the deepening of the channel between Emden and the sea, have been quite recently carried out, and will probably promote the traffic between seaports and the canal. In the event, also, of the extensions to the Rhine and the Elbe being carried out, the portion of the canal between Herne and Bevergern, a distance of about 62 miles, would become part of the important waterway between the Rhine and the Elbe and the extensions to the Oder and the Vistula, Fig. 24, Plate 7.

Fig. 22. *Fig. 23.*



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THE RIVER WESER AND THE PORTS OF BREMEN AND BREMERHAVEN.

Although the ports of Bremen and Bremerhaven were visited by the Congress, and the River Weser was traversed for a short distance below Bremen, and along the whole of its estuary channel between Bremerhaven and the North Sea, the works, as they existed in 1897, were so fully described and illustrated by the engineers in charge of them, in the Paper on "River Regulation Works, and Harbour and Canal Construction in Germany,"[1] published by the Institution in 1899, that a very brief reference to the river and its ports will suffice, with some supplementary particulars.

Improvement of the Lower Weser.—The regulation and dredging of the Weser between Bremen and Bremerhaven, a distance of 42 miles, since 1887, has converted Bremen into a seaport, the navigable depth having been increased by the works from 9 feet up to 19 feet at the present time, which it is proposed eventually to augment to 22 feet by dredging. The river has been straightened, bends have been eased, minor channels closed, and shoals removed; and the low-water channel has been trained by low-tide training walls, with just sufficient width between them to provide for the low-water flow; whilst the high-water channel has been kept as large as practicable, to maintain the original tidal capacity to its fullest extent, and to admit of its increase by the regulated and deepened channel, with the resulting lowering of the low-water line. The trained channel, moreover, has been enlarged seawards to the extent of 1 in 71 in proportion to its length, so as to ensure the complete filling of the channel by the flood tide.

In addition to the increase in the navigable depth, the tidal limit has been extended from Bremen to 5 miles higher up the river by the improved channel, and the discharge of the floods of the river has been accelerated; whilst the increased tidal flow and ebb have diminished the liability of the river to be blocked by ice in the winter.

The continuous improvement in the depth of the channel leading to Bremen is indicated by the fact that, whereas in 1891 only two vessels with a draught of 16½ feet of water, or over, reached Bremen, the number amounted to 47 in 1894, 122 in 1897, and attained 220 in 1901. The total cost of the improvement works up to the end of March, 1902, including the deepening by

[1] Minutes of Proceedings Inst. C.E., vol. cxxxv. p. 224, and Plate 5.

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dredging and maintenance, amounted to £1,515,000, at which period 51,300,000 cubic yards of material had been removed from the river by dredging.

Improvement of the Weser Estuary Channel.—The improvement of the estuary channel forming the approach to Bremerhaven from the sea, commenced in 1891, has comprised a low-water training wall, 4⅓ miles in length, forming a prolongation of the left bank beyond the outlet of the river opposite Bremerhaven, thereby restricting the channel between it and the adjacent right shore of the estuary, some minor training works further out, the closing of side channels so as to concentrate the tidal flow and ebb into a single central channel, and the deepening of the regulated channel by dredging. The regulation of the channel through the outer sandbanks is being gradually carried out, in a tentative manner, according as the alterations in the banks appear to render expedient. The maintenance of the depth obtained by the restriction of the channel, and the removal of shoals formed by abrupt changes in the sandbanks, are effected by two powerful suction dredgers, with hopper capacities of 1,112 and 1,308 cubic yards respectively.

A depth of 26¼ feet below low-water level has been nearly obtained throughout the channel, affording an available depth of 33 feet for incoming vessels, and 29½ feet for outgoing vessels. The cost of the improvement of the channel through the estuary, up to the end of March, 1902, amounted to £460,000.

Port of Bremen.—The accommodation for shipping at Bremen remains about the same as it was in 1897, with one basin and a timber-pond, together with a petroleum basin and two small havens alongide the river.[1] Works have been commenced, however, for the formation of a second basin, which is to be 5,643 feet long, 328 feet to 360 feet broad, and surrounded by sheds; whilst an extension of the timber-pond is proposed. This increase in the accommodation appears to be demanded by the rapid augmentation of the traffic; for whereas in 1891 the number of vessels coming to Bremen was 1,530, with a tonnage of 317,006 tons, these figures had risen in 1896 to 1,729 ships and 648,448 tons, and in 1901 to 2,140 ships and 933,298 tons.

Port of Bremerhaven.—The dock extensions completed in 1897 have enabled the port to meet the requirements of the shipping, the trade having increased from 1,433 vessels with a tonnage of 960,342 tons in 1896, up to 1,715 vessels with a tonnage of 1,667,548

[1] Minutes of Proceedings Inst. C.E., vol. cxxxv., Plate 5, Fig. 2.

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tons in 1901. A large graving dock, however, has been completed since 1897, capable of receiving vessels up to 741 feet in length and 82 feet beam; and its sill is 34⅔ feet below mean high-water level. This dock can be pumped dry in 2½ hours. The North-German Lloyd Shipping Company have constructed an experimental water-tank, 538 feet long, 19⅔ feet broad, and 10½ feet deep, for testing the resistance of models of vessels of different forms when drawn through the water, according to Mr. William Froude's method.

The gates, bridges, and ordinary travelling cranes are worked by hydraulic power; but the powerful high cranes are worked by electricity, and some of the small cranes by gas-engines. There are three high, revolving, counterbalanced, cantilever cranes at the port, one capable of lifting weights of 150 tons in ordinary working,[1] and tested up to 200 tons, (Fig. 40, Plate 7,) and two 50-ton cranes.

Kaiser-Wilhelm Canal.

The canal which provides a short route between the North Sea and the Baltic across Holstein, and affords the German fleet in Kiel Harbour direct access with the North Sea wholly through German territory, is now known in Germany as the Kaiser-Wilhelm Canal. A Paper on the "North Sea and Baltic Canal,"[2] by Mr. Max am Ende, M. Inst. C.E., gave a description of the work, without illustrations, soon after its completion; and a short account of the canal, with a small plan and longitudinal and cross sections, is contained in the Paper already referred to on "River Regulation Works, and Harbour and Canal Construction in Germany."[3] In the small plans of the locks accompanying that Paper, however, the central pairs of gates provided both at Brunsbüttel and Holtenau, have been omitted; and, accordingly, a larger plan of the locks, with these omissions rectified, has been given in Fig. 27, Plate 7.

General Features of the Canal.—The canal, constructed in 1887–95, has been made with a uniform water-level throughout, corresponding to the mean sea-level of the Baltic, as the route of the canal, from the Elbe at Brunsbüttel to Kiel Harbour in a sheltered bay of the Baltic, passes through fairly low-lying land, since in its course of 61⅓ miles, the surface of the ground in the deepest cutting

[1] Zeitschrift des Vereines deutscher Ingenieure, 1899, vol. xliii., Plate 22.
[2] Minutes of Proceedings Inst. C.E., vol. cxxiii. p. 415.
[3] *Ibid*, vol. cxxxv. p. 246, and Plate 6, Fig. 15.

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reaches only 77 feet above the water-level of the canal. Regulating locks at each end shut off the canal from the variations in the level of the Baltic resulting from wind, with a maximum range of 10⅝ feet above, and 6⅞ feet below the mean, and from the changes in the height of the Elbe due to the tides and floods, ranging between 17½ feet above, and 10½ feet below the normal water-level in the canal. As the canal is approached through the sheltered River Elbe at one end, and through Kiel Bay at the other, no works beyond wide entrance-channels leading to the locks, were needed at its extremities.

In constructing the canal through 6½ miles of marshy land towards the Brunsbüttel end, banks of sand had to be tipped along each side of the line of the canal before excavating the trench for the canal between them; and these sand-dams, sinking down into the bog, served to keep back the soft, semi-fluid material on each side from sliding into the excavations, and provided firm soil in which the side slopes of the canal could be formed without danger of slipping, and a support for the embankment along each side of the canal, Fig. 28, Plate 7.

The canal has a depth of 29½ feet, a bottom width of 72⅓ feet in the straight portions, widened out along the curves in proportion to the curvature, and side slopes of 3 to 1 and 2 to 1, with a berm on each side to allow for future widening. For a few feet above and below the water-level, the slopes are pitched with stone, which, in some places where it has been displaced, has been renewed with a layer of small bricks. The regulation speed of vessels on the canal is about 6¼ miles an hour; and even a small steamer going at a speed of 10 miles to 12 miles an hour, creates a wave which rises above the pitching on the slopes.

Two fixed, high-level bridges have been erected across the canal, with a single, arched span, carrying in each case a double line of railway and a road. The Grünenthal Bridge has a span of 513½ feet, and the central portion of the roadway is suspended from the arch, Fig. 29, Plate 7; whilst the Levensau Bridge has a span of 536 feet, and carries its roadway at a higher level in relation to the arch, Fig. 30, Plate 7; and both bridges afford a clear headway of 137¾ feet above the water-level.

Regulating Locks at Brunsbüttel and Holtenau.—The two pairs of regulating locks opening into the Elbe at Brunsbüttel, and into Kiel Harbour at Holtenau, are precisely similar, except in respect of height, each lock having an available length of chamber of 492 feet, a width of 82 feet, and a depth of water over the sills of 31¼ feet with the normal water-level in the canal, and being provided

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with six pairs of gates, placed in pairs pointing in opposite directions, at the two ends, and in the centre of the lock, so that vessels can be locked up or down, into or out of the canal, according to the relative water-levels in the canal and outside,[1] Fig. 27, Plate 7. Under ordinary conditions, the canal admits of the passage through it of vessels 443 feet long, 65⅔ feet beam, 26¼ feet draught, and having masts not exceeding 131¼ feet in height; but as the Holtenau locks are kept open so long as the water-level of the Baltic does not differ by more than 1⅔ foot from the water-level of the canal, and the Elbe is generally level with the water in the canal at some period of the tide, longer vessels could pass through the canal than provided for by the lock-chamber. One lock of each pair is used for incoming vessels, and the other for outgoing vessels. The locks at Brunsbüttel are raised 9 feet higher than at Holtenau, to protect the low-lying lands from flooding by the greater rise of the Elbe resulting from the tides and floods. The steel gates pointing outwards in the Brunsbüttel locks for excluding the Elbe, are each 52½ feet high, 46¼ feet long, and 4½ feet wide, and weigh 121 tons; and the gates pointing towards the canal are only 36¾ feet high, and weigh 107 tons. The gates are generally closed against the Elbe on the arrival of the flood tide, so as to exclude the muddy river water from the canal.

The central pairs of gates of the locks are provided with large openings closed by sliding panels, in order to facilitate the closing of the lock when a current is flowing through it; for the large openings enable the proper pair of central gates to be shut across the lock against the current, which are then closed by the panels and stop the current; after which, one of the end pair of gates can be readily closed in the still water. This arrangement is specially necessary at the Brunsbüttel outlet, where the surplus water flowing into the canal from streams, has frequently to be discharged during ebb-tide in the Elbe, and the lock-gates have eventually to be closed against the outflowing current.

Silting and Dredging in the Canal at Brunsbüttel.—The very muddy Elbe, in filling at every tide the entrance-channel to the canal, closed at its upper end by the lock-gates, deposits large quantities of silt in the fairly still water, the annual deposit in the 12½ acres occupied by the entrance-channel having been estimated at 628,000 cubic yards to 654,000 cubic yards of mud, equivalent to a layer having an average thickness of about 32 feet

[1] "Geschichte des Nord-Ostsee-Kanals," Carl Loewe, Berlin, 1895, Plates 2 and 4.

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over the whole surface.[1] This necessitates almost constant dredging in the channel to maintain the standard depth of 29½ feet; and this is effected by a suction dredger, which draws up in its pipe, and deposits in its hopper, a stream of thick mud of the consistency of paste, which settles at once in the hopper. This dredger, purposely designed for the rapid and economical removal of the very fine mud deposited by the Elbe, has been provided with a special apparatus attached to the end of its suction-pipe, whose level on the bottom can be adjusted with precision, by means of a crane overhanging the stern of the dredger, from which the girder carrying the suction-pipe and apparatus, is suspended by chains. The special apparatus consists of two parts; first, a sort of large dredger bucket in front, which fills itself by scooping up the silt from the bottom as the dredger steams slowly forward; and, second, a closed box or receiver at the back of the bucket, into which the silt, after filling the bucket, is gradually forced, and in which it is mixed with the exact quantity of water requisite to give it the fluidity necessary to enable it to be drawn up the suction-pipe, the water being introduced into the receiver under pressure by a pipe, the flow through which is regulated by a valve controlled from the deck of the dredger.[2] The silt, after admixture with water, is drawn up from the receiver through the suction-pipe, and can then either be delivered into the hoppers of the dredger, or into hopper-barges alongside, or can be forced through a long delivery pipe, and deposited on land at the side of the canal. In the dredger specially constructed for the work after experimental trials, the bucket and receiver have been given an effective width of 11½ feet, so that a strip of this width is dredged in one operation; this dredger can raise 1,300 cubic yards of mud from the channel at Brunsbüttel, on the average, in an hour; and, in a working day of 10 hours, it can raise, deposit in its hoppers, and discharge nearly 2 miles away, about 4,600 cubic yards of mud, at an average cost, for working expenses, of £7 10*s.* a day. The advantages of this system are that by employing the smallest amount of water consistent with fluidity, the silt is raised from the bottom with a minimum amount of pumping, and also in such a condition that it settles directly in the hopper, without the long delay and

[1] The Author is indebted to Mr. Oswald Blenkinsop, of Rendsburg, Inspector of the Machinery on the Canal, for particulars as to the deposit, and statistics of the traffic on the Canal. Mr. Blenkinsop also showed the Members of the Congress the dredger at work close to the Brunsbüttel locks.

[2] "The Suction Dredger 'Nicolaus,'" N. Scholer, Düsseldorf International Navigation Congress, Section II, Communication 3.

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loss from efflux with the water overboard, which commonly occur in discharging fine silt or sand into a hopper from the suction-pipe of a dredger, mixed with the ordinary large volume of water. Deposit also takes place in the canal, along a short distance above the Brunsbüttel locks, from the water of the Elbe introduced in locking down into the canal from the river; but this is partially removed by the scour of the water discharged from the canal every fifth or sixth day. The water entering the canal from the Baltic is clear; and no deposit has hitherto been observed in any other part of the canal.

Appliances on the Canal.—The lock-gates, sluice-gates, and capstans at the locks are worked by hydraulic power, generated in each case close to the locks. The lock-gates are moved by direct-acting pistons working in cylinders placed in the side walls.

The canal is lighted at night by electric glow lamps all along the canal, together with some arc lights at the locks, the electricity being generated at stations established at Brunsbüttel and Holtenau.[1] The lamps, about 1,000 in number, are placed along each bank of the canal, at intervals of 820 feet in the straight portions, and closer along the curves in proportion to the curvature, being placed only 262 feet apart along the sharpest curves of about 50 chains radius. There appears to be an impression in Germany that this is the only instance of a canal lighted throughout its length, owing to ignorance of the fact that the Soulanges Canal in Canada, the most recently completed link of the enlarged St. Lawrence canals, is lighted throughout its length of 14 miles by electric arc lamps of 2,000 candle-power at intervals of 480 feet.

Traffic on the Kaiser-Wilhelm Canal.—The traffic on the canal for each year ending on 31 March, since its opening on 1 July, 1895, is given in the following Table: but these returns do not include the considerable number of vessels of war, belonging to the German and foreign navies, which have passed through the canal.

Most of the steamers, and especially those of large tonnage, pass right through the canal; whilst about half the sailing vessels, and somewhat less than half the barges, chiefly the larger ones, also traverse the canal from end to end. The number of vessels, and also the tonnage, with the exception of 1901–02, exhibit a steady increase; whilst a decrease of traffic in 1901 is noticeable at most of the principal Rhine ports, and also at Hamburg, *Fig. 12.*

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[1] "Der Kaiser-Wilhelm Kanal und seine elektrische Beleuchtung," Helios, Elektricitäts- Aktiengesellschaft, Köln, 1895.

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YEARLY TRAFFIC ON THE KAISER-WILHELM CANAL.

Year.	Number of Vessels.			Registered Tonnage of Vessels.		
1 April to 31 March.	Steamers.	Sailing Vessels.	Barges.	Steamers.	Sailing Vessels.	Barges.
	No.	No.		Tons.	Tons.	
1895-96	7,513	9,303		1,140,578	365,405	
1896-97	8,287	11,673		1,407,435	411,023	
1897-98	9,396	13,712		1,927,946	541,849	
1898-99	11,005	14,811		2,467,839	650,001	
		No.	No.		Tons.	Tons.
1899-1900	11,277	13,248	1,754	2,748,918	492,121	247,728
1900-01	12,269	15,035	1,741	3,489,292	523,748	269,054
1901-02	12,554	15,418	2,189	3,416,337	514,896	354,086

Remarks on the Kaiser-Wilhelm Canal.—Although the commercial traffic along the canal may not be as large as was anticipated, it has steadily increased; and as the canal was constructed for naval purposes, and not primarily for commerce, the traffic it has attracted is so much to the good towards the repayment of the cost of the works undertaken as a measure of national importance. The value of the waterway, in view of the large fleet usually stationed in Kiel Harbour, and the growing importance of Kiel as a naval arsenal, is sufficiently evident; but the canal, with a bottom width of only 72 feet and six passing places in sixty-one miles, would require to be widened if it should ever be called upon to provide for a large traffic. Thus its width compares unfavourably with the bottom width of the Soulanges Canal of 96 feet, with a depth of 17½ feet, only intended to accommodate vessels of about 2,000 tons and 14 feet draught. Provision, however, has been made to some extent on the Kaiser-Wilhelm Canal for a future widening, by means of the berm formed at the side in constructing the canal.

CONCRETE GRAVING DOCKS IN KIEL HARBOUR.

Kiel Harbour, with its perfect shelter, deep water, and extensive foreshores, forms an ideal position for a naval station, especially now that it possesses direct access to the North Sea as well as to the Baltic. It is, therefore, natural that its accommodation for building and repairing ships is being extended. In addition to a

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large shipbuilding yard, covered in with glass and furnished with the most modern appliances, recently constructed by Messrs. Krupp, comprising seven slips for the building of vessels, known as the Germania Dockyard, two concrete graving docks are in course of construction in the water, on the verge of the harbour, by the aid of compressed air.

Description of the Graving Docks.—The two graving docks are being constructed side by side in a recess of the harbour. The largest graving dock hitherto available in Kiel Dockyard is 423¼ feet long and 71 feet broad, and has 27¼ feet depth of water over the sill, which is not adequate for admitting the newest vessels of war. Accordingly, these two graving docks are being made 574 feet long, 95 feet broad, and with their sills 37 feet below sea-level.[1] A ship-caisson is provided for closing the outer end of the dock, and is used for shutting off the enclosure from the bay as soon as the side walls have been raised above the water-level, enabling the water to be pumped out of the dock, and the work inside to be finished off in the open air, which was the state that the most advanced graving dock had reached in the summer of 1902. The docks are designed to be closed, under ordinary conditions, by a rolling caisson, placed 28 feet further in than the ship-caisson at the entrance, for providing the normal length of dock of 574 feet; but, if necessary, the available length of the graving docks can be increased to 602 feet by closing the dock at its outer end by the ship-caisson, leaving the rolling caisson in its chamber. An inner sill, with a chamber for a caisson in the central wall separating the two docks, affords provision for reducing the length of either of the docks to 459 feet for repairing a shorter ship.

Construction of the Graving Docks.—The foundations, bottom, side walls, and altars are formed of concrete, the altars being faced with a course of brickwork. Each cubic yard of concrete is composed of ½ cubic yard of mortar mixed with $\frac{9}{10}$ cubic yard of broken granite, basaltic lava, and clinkers; whilst the mortar consists of 2½ parts of lime, 3 parts of trass, and 4 parts of sand. The foundations are formed of successive layers of concrete extending across the whole width of each graving dock, deposited by means of a floating diving-bell suspended from two barges and supplied with compressed air, which is sunk, when in the required position, by filling a cylindrical air-compartment, of 131 cubic yards capa-

[1] "Bau zweier Trockendocks auf der Kaiserlichen Werft zu Kiel," H. Mönch. Kiel, 1902.

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city, with water.[1] The bell is readily floated again for removal to another position, after the completion of a layer of concrete, by driving out the water again from the compartment by the admission of compressed air. The bell is 137½ feet long, 46 feet wide, and 16⅔ feet high, with a working chamber underneath, having a height of 8½ feet; and it is placed lengthways across the line of the graving dock, so that it can deposit a layer of concrete across the full width of the foundations of one of the docks, amounting to 131 feet, and for a length of about 43 feet along the line of the dock, with a maximum average thickness of about 2¾ feet. Since, on depositing two adjacent layers of concrete, an interval is necessarily left between them, owing to the space occupied by the sides of the bell, the layers in the next row above are not superposed on the ones underneath, but are placed so as to break joint, as in brickwork or masonry, thereby enabling the intervals to be filled up in depositing the concrete for the succeeding layers.

After the foundations, the bottom of the dock, and the lower portions of the side walls and altars, up to about 10 feet below sea-level, have been constructed, the side walls are raised out of water by successive layers in a similar manner, deposited from a smaller diving-bell, 33 feet long and 23 feet wide, and having a working chamber, 6½ feet high, surmounted by a flotation-chamber 8½ feet in height. Whereas, however, the large diving-bell can be readily floated into its successive positions, the small diving-bell, with its smaller area and higher positions in the water, is not stable enough to be thus floated about; and it has, therefore, to be rigidly connected with its supporting barges.

The outer part of the work has had to be founded on a dredged bottom, at a depth of 60⅔ feet below sea-level. To provide against injurious effects to the men working under compressed air, from too sudden changes of pressure, a period of 1 minute for every one-tenth of an atmosphere was prescribed in going into the working chamber, and 2 minutes for each one-tenth of an atmosphere in returning to the open air again.

The Elbe-Trave Canal.

The opening of the Kaiser-Wilhelm Canal, connecting the Elbe

[1] The Author is indebted to Mr. George Franzius, the engineer of the works, both for explanations on the spot, and also for particulars as to the concrete foundations sent to him subsequently, with a quite recently printed description of the works.

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with the Baltic, threatened to draw away the trade from the old Baltic port of Lübeck, on the River Trave a short distance from its mouth, whose only connection with the Elbe was an ancient, very shallow, and small canal. Accordingly, in 1896, the works for a new canal from the Elbe to Lübeck, adapted to modern requirements, were commenced.

Description of the Canal.—The canal starts from Lauenburg, the next large town on the Elbe above Hamburg, and following the valley of the River Delvenau, which flows into the Elbe at Lauenburg, it rises by two locks to its summit-level near Witzeeze, 6¼ miles from its commencement. This reach is 18½ miles long; and after crossing the water-parting between the Elbe and the Baltic, the canal passes through Mölln Lake, and then descends by five locks, in a distance of 10¾ miles, to the level of the River Trave, which it joins about 1¼ mile before reaching Lübeck, Fig. 31, Plate 7. The length of the waterway between the Elbe and Lübeck is just under 40 miles; but including the deepened Trave through Lübeck to the port at the lower end of the town, the total length is 41⅜ miles. The summit-level of the canal is 23½ feet above the mean water-level of the Elbe at Lauenburg, and 39⅓ feet above the mean water-level of the Trave at Lübeck. The lift of the locks ranges between 5⅜ feet and 13¾ feet; but during the lowest stage of the Elbe, the lift of the first lock at Lauenburg attains 18 feet.

The canal has a bottom width of 65⅜ feet, a width at the water-level of 104 feet, and a depth of 8½ feet, which is liable to be reduced in the top reach during dry weather to 6 feet 7 inches, Fig. 32, Plate 7. Along low ground, the banks on each side, with the towing-path, are raised 6 feet to 7 feet above the ordinary water-level of the canal. The section of the canal is very similar to that of the Dortmund-Ems Canal, having a slightly greater bottom width; and it is in conformity with the standard dimensions fixed for new German waterways. The sharpest curve on the canal has a radius of 35½ chains. The canal was opened in 1900, and its cost amounted to £1,177,700.

Locks on the Elbe-Trave Canal.—The locks on the canal constitute a very interesting feature of the works, as they have been constructed so as to be worked on an entirely novel principle. The locks have a minimum depth of water of 8½ feet over their sills, and in the lowest locks 10 feet; they are closed at their upper end by a single gate, turning on a horizontal axis on the sill, and falling flat on the apron for opening the lock; whilst the lower end is closed by two mitred gates, as usual for large locks,

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Figs. 33 and 36, Plate 7. The locks have an entrance width of 39¼ feet, a width of 55¼ feet in the lock-chamber for a length of 193¾ feet, and a total available length of chamber of 262½ feet; whilst the minimum depth of water over the sills is 8½ feet. One to three side ponds are provided at the locks to save water in locking.

The lock-chamber is filled and emptied through siphons interposed in the sluiceways in the side walls, Figs. 33, 34, and 35, Plate 7. An air chamber placed in one of the side walls of the lock towards its lower end, can, by means of valves, be filled with water from the upper reach through the upper sluiceway in the side wall, and emptied into the lower reach through the lower sluiceway, thereby alternately driving air out of the chamber and drawing it in,[1] Figs. 33 and 35, Plate 7. This air collector is connected by a pipe with the valve house, through which it can be placed in communication, by means of a series of air pipes, with the top of each of the siphons on each side of the lock, the pipes from the siphons on the far side being carried under the apron at the head of the lock, or it can be connected by pipes, from the valve house, with a compressed-air chamber placed low down in the wall near the head of the lock on the same side, Figs. 33, 34, 35, and 37, Plate 7. The flow through the siphons is started, for filling the lock-chamber or emptying it, by putting the upper or lower siphons respectively in direct communication, at the valve house, with the pipe from the air collector when this chamber is being emptied of water, thereby causing air to be drawn from the top of the siphons into the air collector. When, on the contrary, the air collector is being filled with water, the pipe issuing from the top of this chamber to the valve house is put in communication with the compressed-air chamber; and the water drives the air out of the air collector to the compressed-air chamber, where it is stored up. The supply of compressed air thus provided is used for closing the gates of the lock, being connected by pipes with the bottom of the falling upper gate on each side, and with two wells in the side walls near the lower gates, in which a kind of diving-bell moves up and down, connected with the direct-acting piston closing and opening each gate.

When the upper gate has to be raised, communication is made through the pipes on each side with the compressed-air chamber; and the air passes along the side of the gate into the air chamber

[1] Zeitschrift des Vereines deutcher Ingenieure, 1899, vol. xliii. pp. 614–617 and 1900, vol. xliv. pp. 753–785.

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at the top, forcing out the water and making the gate rise by flotation into a nearly upright position, Fig. 36, Plate 7. When the gate has to be lowered, the compressed-air supply being shut off, the flotation-chamber fills again with water; and the gate, turning on its axis, sinks again to a horizontal position on the apron, as shown in Figs. 33 and 36, Plate 7. For closing the lower gates, compressed air is admitted through the pipes into each well, forcing the bell up, and thus causing the piston to close the gate. When the pressure of the compressed air is removed, the bell sinks in the well, and, drawing along the piston, opens the gate on each side. All the operations of filling and emptying the lock-chamber, and working the gates, are controlled at the valve house, Fig. 33, Plate 7. At the Krummesse Lock, with a lift of 9 feet, the closing of the pair of lower gates and the lowering of the upper gate (occupying only a minute) the starting of the siphons, and the filling of the lock-chamber alone, are effected in 7 minutes; but when the side pond is utilized, the operation is prolonged to 10 minutes.

Cost of Works for Port of Lübeck, and Traffic on Canal.—In addition to the £1,177,700 expended on the canal works, the River Trave has been regulated and deepened from Lübeck to the Baltic at a cost of about £458,000; and since 1872, a sum of £409,170 has been spent in extending and deepening the port of Lübeck. The total amount, accordingly, expended in improving the access to Lübeck, and increasing its facilities and accommodation for traffic, including the cost of a tug, is altogether about £2,050,000.

In 1901, the year after the opening of the canal, the traffic on the canal consisted of 2,270 vessels of 412,456 tons burden, and laden with 219,891 tons of merchandise.

The Port of Hamburg.

A description of the port of Hamburg in 1896 has been given in the Paper on German harbour works previously referred to[1]; but important recent extensions of the basins are approaching completion, and large improvements in the equipment of the port have been effected since that time.

Extension of the Port.—Since 1896, three large basins, B, C, and D, have been constructed in low-lying land on the left bank of the Elbe, below the older basins, but included within the limits of

[1] Minutes of Proceedings Inst. C.E., vol. cxxxv. p. 240, and Plate 6, Fig. 10.

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the free port, to meet the requirements of a rapidly growing traffic; and the coal basin, just outside the free port, has been prolonged, Fig. 38, Plate 7. These basins are being made deeper than the previously existing basins, to provide for the increasing draught of ships; for whereas the deepest of the older basins afford a depth of 20⅔ feet at low tide, and nearly 27 feet at high tide, basin B has been given a depth of 24 feet at low tide, and 30½ feet at high tide; and basins C and D are being made about 2¼ feet deeper still, so as to provide a depth of 26¼ feet at low water, and 32½ feet at high water. Basin B is surrounded with slopes at the side supported by a pilework toe, with masonry jetties on bearing piles projecting across the slope at intervals, having been originally designed to accommodate sailing vessels; but basins C and D are lined throughout with quay walls built upon piles, according to the usual system, both at Hamburg and Bremerhaven, in these silty alluvial foundations, Fig. 39, Plate 7.

The approach channel to the port along the Elbe is somewhat obstructed by a bar below the town, and appears not to possess an available depth commensurate with the increased depth being provided in the new basins, and the increasing draught of vessels. Some training works, and dredging with a bucket-ladder dredger, have been carried out below Hamburg; but considering that the shoals in this part of the Elbe are composed wholly of sand, sand-pump dredgers would provide the most efficient means for obtaining the requisite depth in the navigable channel.

New Sheds on the Hamburg Quays.—The oldest sheds in the port are quite open on the basin side; whilst some later ones are closed, being provided with doors at intervals. The most recent sheds, however, are shut in along the basin side by a continuous line of sliding doors, so that, although enclosed when required, they can be opened to the basin at any desired point. Some of the most recent sheds, erected alongside the Sailing-Ship and Hansa basins, have been given a width of 111½ feet, being wider, higher, and better lighted from the roof than the earlier ones; and they are formed in one continuous length, without any intermediate partitions. The sheds in course of erection along the quays of the new deep-water basins, will vary in size between 1,013 feet long and 138 feet wide, and 1,312 feet in length and 164 feet in width; and they are to be shut in with sliding doors on the side of the basins, Figs. 38 and 39, Plate 7.

Special provision is made for the maintenance of an adequate temperature in winter in the sheds set apart for the storing, inspection, and sale of fruit, and also for their ample lighting and

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ventilation. These sheds are constructed with a double roof and double wooden walls; and steam-heating apparatus is installed in them, so as to secure the temperature inside from ever falling below 45½° F. The fruit sheds, moreover, are furnished with extra lights in the roof, and with channels under their floors for ventilation.[1]

Cranes in the Port of Hamburg.—The quays surrounding the basins of the port are very well equipped with travelling cranes, worked on different systems. The older cranes are worked by hand or by steam, being capable of lifting 1 ton, and 1½ ton to 2½ tons for the most part, respectively. Some of the steam cranes are supplied with steam through pipes from a central station; but the loss of heat in transmission naturally renders the system costly, although possessing conveniences as compared with separate steam-engines. There are five steam-cranes of 5 tons, and one 7½-ton steam-crane. A few fixed cranes are worked by hydraulic power, and by gas-engines.

Electric cranes of 2½ tons to 3 tons have recently been introduced on the northern side of the Beacon Basin, on the south-western side and at the end of the Sailing-Ship Basin, and on the north-eastern side of the Hansa Basin, travelling on one rail along the edge of the quay wall, and the other on the top of the side wall of the shed; whilst electric cranes are to be installed in front of the sheds of the new basins. The cranes are placed along the quays in front of the sheds, at intervals of about 65 feet to 72 feet. The current was originally furnished from the town installation; but recently a generating-station has been established on the quays in the southern part of the port, to provide the requisite electric power independently for working the cranes.

The large revolving 150-ton crane of the port resembles a sheer-legs, and is worked by steam; but there is a new 30-ton crane at Hamburg, of the high, counter-balanced, cantilever type, worked by electricity, resembling in principle the Bremerhaven 150-ton crane, (Fig. 40, Plate 7) already referred to; and there is another very similar, one of 150 tons, in one of the dockyards at Kiel. Altogether, there are about 590 cranes at the present time in operation at Hamburg.

The large vessels trading with the port do not appear to make

[1] Mr. Paul Winter, the Director of the Quays at Hamburg, showed the Author, with some other foreign engineers, over the quays of the ports after the termination of the visit of the Congress; and he has since kindly furnished the Author with particulars of the sheds, cranes, and traffic of the port.

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as much use of the ample equipment of the quays as might be anticipated; for with the exception of certain quays leased to two or three companies possessing lines of steamers, only the smaller steamers are allowed to lie alongside the quays, and they can only remain for a period of five days. The large steamers, and also the smaller steamers if they have not completed their operations within the assigned period, have to lie moored to dolphins in the middle of the basins, or in the river, with barges, lighters, or river vessels alongside them, into which they discharge, or out of which they receive, their cargoes, involving, as it would appear, a considerable amount of unnecessary transhipment.

Traffic of the Port of Hamburg.—The upper line on the diagram of traffic, *Fig. 12*, shows the combined weights of maritime goods entering and leaving the port each year from 1872 to 1901. It is evident from the diagram that, with but few checks, as in 1873–74, 1885, 1892, and 1901, the commerce of the port has increased very rapidly and steadily, especially from 1893 to 1900. The imports and exports exhibit very similar features in their growth; but although the imports have always largely exceeded the exports in weight, their proportionate increase has not been so great; for whereas the imports in 1872 amounted to three times the weight of the exports, the imports are now only about double the weight of the exports. Thus in 1872, the imports were 2,137,903 tons and the exports 678,466 tons; in 1885, the imports were 3,163,644 tons and the exports 1,911,592 tons; and in 1901, the imports reached 9,701,346 tons and the exports 4,695,469 tons. The value in 1900 of the maritime imports to Hamburg, attained £114,040,000, and the exports seawards £90,550,000; and the exports thus approximate much more nearly to the imports in value than in weight.

Of the registered tonnage of the vessels entering the port of Hamburg, amounting to 8,383,365 tons in 1901, only vessels representing a total tonnage of 4,722,365 tons came alongside the quays; and out of the above-mentioned total registered tonnage in 1901, 7,535,946 tons consisted of steamers.

Concluding Remarks.—In terminating this summary of some of the most important works, in regard to inland and maritime navigation, carried out in Germany within recent years, the Author desires to express his great obligations to the organizers of the Düsseldorf Navigation Congress, for the opportunity afforded of visiting so many interesting works in the brief period at the disposal of the Congress, and for the useful guide-books presented to the members, giving valuable details of the various works inspected, which have enabled him to prepare this Paper, in which

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he has endeavoured to give a slight sketch of the progress in navigation works achieved in Germany in recent years, the growth of the traffic on some of the new or improved waterways and at their ports, and the projects in contemplation for the further development of inland navigation throughout the empire. The visits to works certainly constitute one of the most important features of international navigation congresses, especially for foreign engineers, in exhibiting the latest experience and the most recent developments in hydraulic and maritime engineering abroad; and the Author hopes that this Paper may, to some extent, serve to afford the Members of the Institution the same extended experience and acquaintance with some of the most recent and novel works in Germany, which he himself has derived from attendance at the Düsseldorf Congress.

One aspect of the works described, which is worthy of notice, is the readiness displayed to undertake works of a somewhat experimental character, such as the suspended mono-rail railway, the floating lift and stop-gates on the Dortmund-Ems Canal, and the falling gate, siphons, and compressed-air system adopted for working the locks on the Elbe-Trave Canal, whereby ingenious schemes are submitted to the test of practical experience. The boldness thus evinced in carrying into execution projects of considerable novelty, is well deserving of commendation as very materially contributing to the advancement of engineering science.

The Paper is accompanied by seven tracings, from which Plates 6 and 7, and the Figures in the text have been prepared.

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(Paper No. 3348.)

"Burraga Dam and Water-Supply for the Lloyd Copper Company's Mine, New South Wales."

By JOHN HAYDON CARDEW, Assoc. M. Inst. C.E.

THE success of mining in Australia depends to a large extent upon the practicability of securing a permanent supply of water; and in many instances the richest mines are situated in the most arid localities, where there are no rivers or creeks, and where the evaporation and the absorption of the soil are so great that the conservation of any large quantity of water is a matter of extreme difficulty. The Lloyd Copper Company's mine at Burraga, in the Bathurst District of New South Wales, is situated in broken and mountainous country at an elevation of 3,000 feet above sea-level, and is reputed to be one of the best low-grade copper-ore mines in Australia. Hitherto the reduction of the ore has been carried out by roasting and the reverberatory furnace, the "matte" being sent 42 miles by road and 53 miles by rail to Lithgow, to be refined, before shipment to London; but now the Company are erecting concentrating machinery and calciners, with a view to doubling or trebling the output, and it is estimated that 180,000 gallons of water per day will be required.

Before determining upon a concentrating plant, the Company instructed the Author to make surveys and investigations of the surrounding country for the purpose of discovering a catchment-area sufficient for the purpose of supplying the requisite water. The valley of Thompson's Creek, a tributary of the Isabella River, was selected as being the only practicable catchment-area available, and a favourable site was selected for the erection of a concrete dam about 3½ miles from the mine. Between this valley and that in which the mine is situated a watershed intervenes, and, in order to discover a route for a pipe-line to connect the reservoir and the mine which should not involve heavy tunnel-works, several trial surveys were made, and eventually a "gap" was found which

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admitted of the pipes being laid to the hydraulic gradient, with a comparatively short length of tunnel, about 25 feet below the surface at the deepest part.

Catchment Area.—The catchment-area of the impounding reservoir embraces 5,329 acres of undulating and mountainous country, timbered principally with white gum and stringy bark. The upper portion of the drainage-basin is of granite formation, the hills being rocky and lightly covered with soil. In the valleys the soil is very porous and sandy, but the lower portion of the creek valley in the vicinity of the dam is a slate formation, the overlying soil consisting of a stiff clay mixed with ironstone gravel, whilst the range of hills abutting on the north and east sides of the reservoir site consists of hard diorite.

Rainfall.—The mean annual rainfall is 28·2 inches, and the greatest rainfall ever recorded in one day is 3 inches, the records having been kept for the last 10 years.

Capacity of Reservoir.—In determining the size of the dam and reservoir, and the quantity of water necessary to be impounded for the supply of the works at the mine, the liability to long periods of drought had to be considered. During the six summer months of the preceding year all the rain that fell was either evaporated or absorbed, and there was no flow in the creeks; it was therefore decided to make the storage equivalent to 1 year's supply, so that the continuous running of the machinery might be assured. As already stated, the requirements of the works were 180,000 gallons of water per day, which, for 313 working days, is 56¼ million gallons per annum; and to this must be added the quantity likely to be evaporated from the reservoir. The Government Astronomer of New South Wales, Mr. H. C. Russell, C.M.G., has for many years past carried out a series of observations on evaporation at Lake George, about 70 miles south of Burraga, and at an altitude of 2,267 feet above sea-level, the results of which, given in his "Meteorology of New South Wales," show that the mean annual evaporation during the 10 years 1886–1895 was 40 inches. As the climatic conditions at Burraga are similar in every respect to those at Lake George, the Author assumed that Mr. Russell's conclusions would be applicable, and adopted 40 inches as the mean annual evaporation. The area of the reservoir is 31 acres, and 40 inches on that area is equivalent to 28¼ million gallons, which, added to the annual requirement of 56¼ million gallons, gave the storage required as 84½ million gallons, and the height of the waste weir was fixed accordingly.

Yield of Gathering Ground.—As the flow in the creeks had never

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been gauged, it was impossible to calculate exactly how much water the catchment area contributed to the streams and what proportion of the rainfall was lost by absorption and evaporation, but for a preliminary estimation it was assumed, after careful examination of the surface, that 65 per cent. was lost by those agencies. The average rainfall of 28·2 inches on the catchment-area of 5,329 acres, less 65 per cent., amounts to 1,193¼ million gallons, or sufficient to fill the reservoir fourteen times every year, leaving 1,108¾ million gallons to pass away down the creek to the settlers below the dam. Just before the dam was completed an opportunity occurred of actually measuring the amount of rainfall contributed to the reservoir, which proved that 72·8 per cent. of the rainfall was lost by evaporation and absorption on the catchment.

Rain commenced to fall on 19 September (the ground surface being fairly moistened with the winter rains and snows, but not by any means saturated) and terminated on 26 October, and during that period the rainfall was 4·78 inches, of which 2·65 inches was contributed in one day; this rainfall was measured by the Government Astronomer's deputy on the spot and recorded daily, and represents a fall of 577 million gallons on the catchment. The reservoir was empty when the rain commenced, and was full on 10 December, after which date the streams leading to it had ceased to flow. During the period of contribution, 35 million gallons were run off by the contractor (this quantity being measured through the sluice-pipe), 4¼ million gallons were evaporated from the reservoir, and 85 million gallons remained in the reservoir, so that in all, the catchment contributed 124¼ million gallons to the reservoir. The percentage of the rainfall actually conserved is therefore $\frac{124 \cdot 25}{577} \times 100 = 21\frac{1}{2}$ per cent. It may readily be conceived that after a prolonged drought, and during the heat of summer, the percentage would be considerably less, as the absorptive and evaporative agencies would be more active; but as the bulk of the rainfall occurs in the winter months, the assumed percentage of contribution may be considered fairly accurate.

Trial Pits.—Trial pits and trenches were sunk right across the site of the dam, and what was supposed at the time to be sound rock was located as shown upon the sections (*Figs. 1*), but when excavation for the foundations of the dam was commenced, and the whole site was laid bare, it was discovered that the rock was so laminated with nearly horizontal fissures, containing clay,

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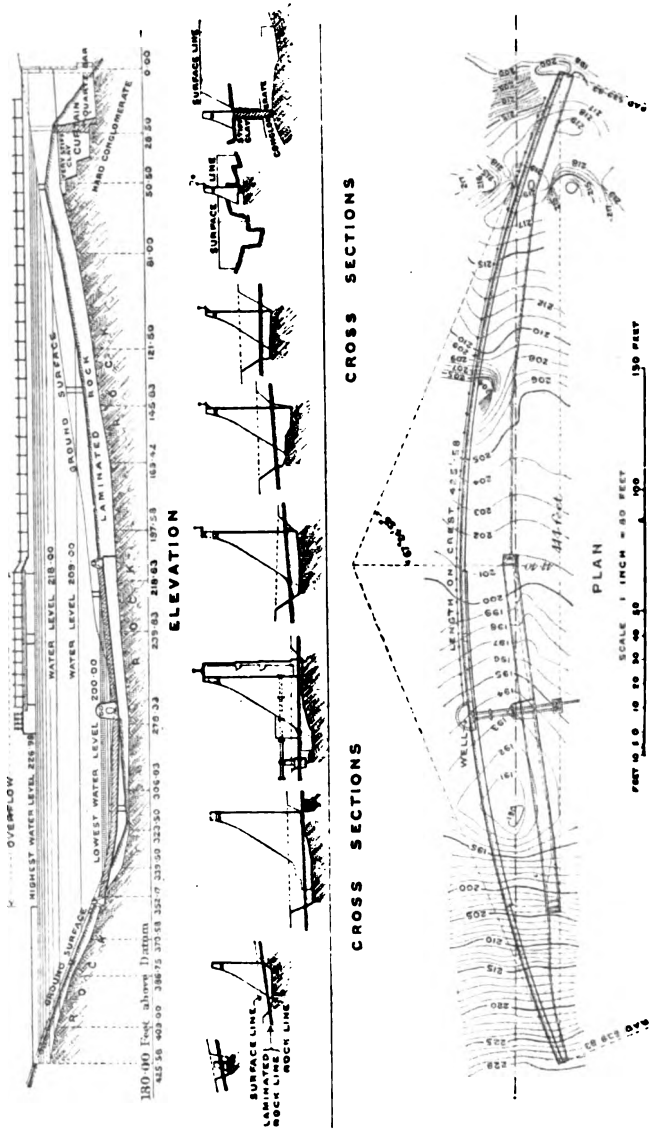
gravel and wash, through which water was flowing, that it was found necessary to remove a much larger body of rock than was

Figs. 1.



at first deemed sufficient, in order to secure a solid rock seat for the dam.

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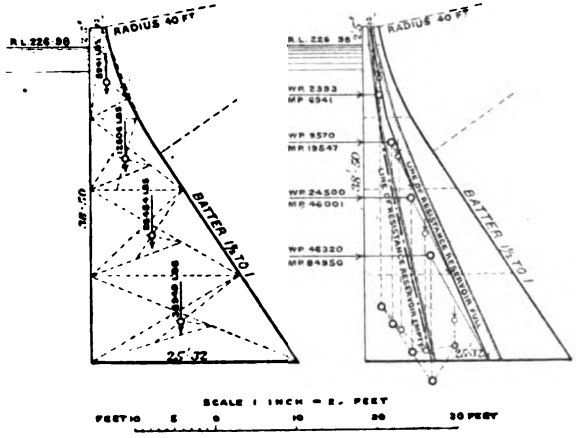
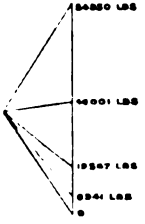
Design of Dam for the Impounding Reservoir.—The dam is curved in plan, the inner face of the wall having a radius of 539·83 feet. The length of the crest measured on the curve is 425·58 feet, and subtends an angle at the centre of 45° 10′ 10″, the versine being 41·40 feet. The dam is designed with a gravity section, and no

Figs. 2.



reliance is placed upon any strength that may accrue on account of its curved form, as it was thought that the southern bank of the creek was not sufficiently abrupt to act as an abutment, the curved form being introduced only to minimise the effects of expansion and contraction. The centre of gravity and centre of pressure were determined graphically, as shown in *Figs. 2* and *3*. The limit of pressure was assumed to be 10 tons per square foot and the density 170 lbs. per cubic foot for concrete masonry. In cross-section the inner face of the dam is vertical, the outer face of the upper part being curved to a radius of 40 feet, and on the lower part battered to a slope of 1 horizontal to 1½ vertical. The greatest height of the dam is 41 feet, the width at the crest being 2 feet, and at the base 25·32 feet. The waste weir was designed as an overfall, and was placed at about the centre of the dam, being calculated to provide for a rainfall of 3½ inches in 24 hours from a full reservoir with three-fifths flowing off. The Author has found during a long experience of flood investigation in New South

Fig. 3.



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Wales, and by the comparison of many observations compiled by the Government Astronomer, that the maximum rainfall for 1 day in this district is very nearly one-eighth of the mean annual rainfall, and that the maximum rainfall for 1 hour is nearly one-fourth of the greatest daily rainfall; in a period of 8 hours the maximum rainfall is double that for 1 hour; in a period of 16 hours it is treble, and in 24 hours four times as great as the rainfall for 1 hour; it was therefore assumed, for the purposes of calculation of the discharge over the weir, that the maximum rainfall for 1 day would be $3\frac{1}{2}$ inches, for 1 hour 0·87 inch, for 8 hours 1·76 inch, and for 16 hours 2·64 inches. Assuming that the rain is general over the whole area, and of sufficient duration to allow the flood-waters from all parts of the drainage-area to reach the dam at the same time, it was determined, after a careful examination of the creeks and gullies, and the slopes of the ground on the catchment-area, that at least 8 hours would be required, after the rain commenced, to reach the moment of maximum discharge at the dam; and, allowing the ratio of diminution of discharge due to area to be $\frac{M^{\frac{3}{4}}}{M}$, the quantity in cubic feet to be discharged was calculated by the Chamier formula,

$$Q = 640 \times R \times C \times M^{\frac{3}{4}},$$

in which—

R = average rate of rainfall in inches per hour = $\frac{1 \cdot 76}{8} = 0 \cdot 22$ for a duration of 8 hours,

C = coefficient of surface discharge, determined by inspection on the ground = 0·60,

M = catchment area in square miles = 8·3,

Q = quantity of water reaching outlet in cubic feet per second = $640 \times 0 \cdot 22 \times 0 \cdot 60 \times 8 \cdot 3^{\frac{3}{4}} = 413$ cubic feet per second.

The length of waste weir required to discharge this rainfall with a depth on the crest of 1 foot 3 inches was found from the formula,

$$L = \frac{Q}{m \times d \times \sqrt{2gd}}, \text{ in which } m = 0 \cdot 30, \text{ to be 123 feet,}$$

but as the inlet-well for the supply-valves projects above the crest of the dam and divides the waste weir into two separate parts, the clear combined width was made 125 feet in order to allow for diminution of discharge due to the contraction at the ends. The outlet-works consist of a semicircular well or valve-chamber with two cast-iron outlet-pipes, 9 inches in diameter, laid side by side,

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leading therefrom through the wall of the dam and provided with stop-valves on their outer ends, one pipe being a reserve in case of emergency. The well is supplied from the reservoir by three 12-inch inlet-pipes, set at different levels in the semicircular wall of the well and controlled by valves supported on brackets and worked by spindles from the platform on top of the well, so that water can be drawn at any desired level. A sluice-pipe 18 inches in diameter is laid through the base of the wall for the purposes of cleaning out and regulating the discharge of the creek waters during construction. A light steel girder-bridge on top of the dam connects the valve-chamber with the shore. The impounding reservoir has an area of 31 acres, and contains, when full to the level of the overflow-weir, 85 million gallons of water; a rainfall of 1 inch on the watershed is sufficient to fill the reservoir.

Construction.—After all laminated and decayed rock had been removed from the foundations, the surface was cleaned off by means of a jet of water at a pressure of 60 lbs. or 70 lbs. per square inch, supplied by a pump, and all crevices and fissures were cleaned out and filled with cement grout, mixed in the proportion of 1 of sand to 1 of cement; a layer of cement mortar in the proportion of 2 of sand to 1 of cement was spread over the surface of the rock to a thickness of ½ inch before any concrete was placed in position. The concrete was laid in courses, 2 feet in depth, extending from one end of the dam to the other, and was of two qualities, the inner face of the dam, for a thickness of 18 inches, consisting of concrete composed of 1 of cement, 2½ of sand, and 3½ of crushed stone to pass through a ring ½ inch in diameter, and the outer face of the dam, for a thickness of 6 inches, being of concrete composed of 1 of cement, 3 of sand, and 5 of crushed stone to pass through a ring 1½ inch in diameter. The heart of the dam was built of blocks of stone set in concrete, locally known as plum concrete, each stone having 6 inches of concrete all round, and no stone being laid nearer than 18 inches to the inner face of the dam, or nearer than 6 inches to the outer face, or within 2 feet of the foundations; the stones were not larger than 16 cubic feet nor smaller than 2½ cubic feet, and were roughly squared and placed with their longest dimensions at right angles to the axis of the dam. All the stones were scrubbed and hosed clean before being laid in the work.

To guard against the effects of frost, which was very severe at night during the winter months, work was suspended before sundown, and all new concrete was covered over with tarpaulins; before resuming work in the morning, the surface of the concrete

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was hosed down with boiling water before the next course was placed in position. Diorite stone of excellent quality was obtained within ½ mile of the dam, its only fault being that it was too hard for the stone-breaker, the jaws of which frequently failed. The following is an analysis of the stone :—

Silica	67·44
Ferric oxide	3·20
Alumina	22·40
Lime	1·12
Magnesia	2·20
	96·36
Specific gravity	2·60

It will be seen that the two essential hydraulic constituents of cement, viz., silica and alumina, are present in this stone, but in much larger proportions than in cement. The stone in passing through the crusher produced comparatively little sand or dust, and it was found that the admixture of a small proportion of the dust with the concrete produced a very beneficial effect both upon the setting of the concrete and upon its strength. The sand used in the concrete was of a very coarse character and quite unsuitable for making a water-tight dam, but the admixture of the dust from the crusher greatly improved the quality of the concrete in that respect. Portland cement was employed, and was specified to bear a tensile stress of not less than 300 lbs. per square inch after 3 days (2 days in water), 450 lbs. per square inch after 7 days (6 days in water), and 550 lbs. per square inch after 28 days (27 days in water); it was required to be so finely ground that the residue on a sieve of 6,400 meshes per square inch, without rubbing, should not exceed 20 per cent., and on a sieve of 14,500 meshes per square inch should not exceed 30 per cent. It was also specified that the cement when gauged with three times its weight of standard sand, crushed from the sandstone, washed, dried, sifted through a sieve of 400 meshes per square inch, and retained upon one of 900 meshes to the square inch, mixed with 10 per cent. of water, made into briquettes, and placed in water for 24 hours, should stand a tensile stress of not less than 100 lbs. per square inch after 7 days, and 200 lbs. per square inch after 28 days. The actual tests of the neat cement showed a tensile strength of 529 lbs. per square inch after 3 days, 607 lbs. per square inch after 7 days, and 664 lbs. per square inch after 28 days. The tests of cement mixed with three times its

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weight of sand showed a tensile strength, after 7 days, of 229 lbs. per square inch, and after 28 days 284 lbs. per square inch. The specific gravity of the concrete in the dam was found to be 2·724. Stout timber centres were erected the full height of the dam, and the casing was erected as the work proceeded. Great care was observed in bedding the stones in the concrete to avoid cavities, and the concrete was thoroughly punned around them; the concrete on the faces was well worked with spades to get a smooth surface when the timbers were struck. It was found that the proportion of "plums" was 33 per cent. of the whole wall.

Stopping a Leak.—When the dam had reached a height of about 20 feet above the bed of the creek, a heavy fall of rain occurred on the drainage area, causing a freshet in the creek, which the sluice-pipe was insufficient to deal with, and the water rose behind the wall to some height. Owing to the immaturity of the concrete masonry, the water forced a passage through a joint, causing a leak just above the root of the apron. In order to plug the hole in the face of the dam and such interstitial voids as might exist in the heart of the masonry, liquid cement was injected under hydraulic pressure. An iron tank holding 400 gallons was placed on the hill-side 50 feet above the leak; a 2-inch wrought-iron pipe was laid from the tank down the slope of the hill to the leak at the foot of the dam, and was connected at one end to the tank, the other end being provided with a valve and a short length of flexible pipe terminating in a nozzle, which was inserted into the orifice of the leak in the face of the dam. The face of the dam for 6 feet above and below the hole and on either side was then planked over with 2-inch hardwood planks, tongued and grooved, with insertion laid between the face of the wall and the planking, a hole being bored through the plank over the leak to allow the nozzle to pass through; the planking was strengthened with hardwood stringers, 4 inches by 4 inches, which were strutted back to the rock and wedged up to hold the planking against the face of the dam and make it water-tight under pressure; the nozzle was then inserted and made perfectly secure and tight by driving home and wedging. The tank on the hill was filled with liquid cement kept in a thoroughly mixed state by men with shovels, and when everything was in readiness the valve was opened and about one-third of the mixing passed down the pipe into the hole. After an interval of 3 days the shores and planking were removed, and it was seen that the hole had been most effectually filled with the cement grout, which, when the water rose behind the dam to

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its full height, was found to be quite water-tight. Although the greatest care was observed in the mixing and laying of the concrete to secure a water-tight wall, it was recognised that the coarseness of the sand would greatly militate against success in spite of the inner face of richer concrete, and it was found as the dam progressed and the water rose in the reservoir that a considerable leakage occurred, which appeared on the down-stream face of the dam like water coming from a very fine rose. To render the inner face with cement mortar made from such coarse sand would not improve matters; it was therefore decided to paint the inner face with neat cement mixed to a slurry, applied with stiff brushes, and well rubbed into the pores in three successive coats; this proved most effective, for when the water rose again in the reservoir the wall was found to be perfectly water-tight.

The expansion and contraction in concrete dams when the reservoir is low is very great, and when the reservoir is full it is very unequal in different parts of the cross-section; this is especially the case in some parts of Australia, where hot days and cold nights are of frequent occurrence, giving a range of temperature of about 90° F., and on that account many of the concrete dams in this country are badly cracked. In order to obviate this tendency to some extent, and to assist the closing of the cracks as the reservoir filled, the curved form of dam was adopted. It has been observed that the curved form does not render the structure altogether immune from cracking, and the cracks occur generally at about one-third of the length of the dam from the wings, commencing at the crest, first as a very fine crack and afterwards opening out and extending down the wall a distance of one-third to one-half of its height, and opening and closing as the reservoir empties or fills. It was thought that the introduction of an iron tie-bar in the crest of the dam, to take the tensile stress due to the contraction, would completely preserve the dam from cracking. It has been proved in other works that the temperature in the heart of the dam, say 3 feet from the surface, is constant, from which it may be argued that in order to ensure safety from cracking it is only necessary to protect from tensile stress the upper or thinner part of the dam where the cracks invariably originate. To find the cross-sectional area of such an iron or steel tie-bar to resist tensile stresses due to a range of temperature of 90° F., the unital stress in the upper part of the wall due to that range of temperature was determined by the formula—

$$\text{Unital stress} = c \times t \times E,$$

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in which—

c = the coefficient of expansion or contraction for concrete for 1° F. = 0·0000076;

t = the range of temperature above or below the average temperature = $\frac{90° \text{ F.}}{2} = 45°$ F.;

E = modulus of elasticity for concrete = 750,000 lbs. per square inch.

Hence the unital stress = 0·0000076 × 45 × 750,000 = 256·5 lbs. per square inch, which is greater than the usual maximum tensile stress allowed in concrete—about 200 lbs. per square inch. The coefficient of elasticity of concrete bears to that of iron the ratio of 1 to 40, and the stresses required to produce the same strain in the two materials are directly proportional to these coefficients, so that assuming that it is undesirable to allow a greater stress than 200 lbs. per square inch in the concrete, and that the cross-sectional area of that part of the wall subject to the effects of temperature is 1,930 square inches, the total tensile stress = 256·5 lbs. × 1,930 square inches = 200 lbs. $(1930-x) + 200\ (40\,x)$, in which x is the cross-sectional area of the iron required; *i.e.*, 495,045 = 386,000 − 200 x + 8,000 x, 7,800 x = 109,045 and x = 14 square inches. Hence two 70-lb. rails would be theoretically sufficient, but in order to provide a margin of safety three 70-lb. double-headed rails were laid, 6 inches below the level of the weir-overflow, and were jointed with fish-plates and embedded in the concrete.

Pipe-Line.—The pipe-line is 16,890 feet in length and conforms to the principal contours of the intervening hills, crossing a low-lying gap in the dividing-range, through a tunnel 1,100 feet in length, *Fig. 4.* The pipe is 9 inches in internal diameter and is constructed of mild wrought steel $\frac{1}{8}$ inch in thickness. It is constructed in lengths of 24 feet and multiples of 24 feet, the plates being 4 feet in length. The longitudinal joints are $1\frac{3}{4}$ inch and the transverse joints $1\frac{1}{8}$ inch in width; the rivets are $\frac{5}{16}$ inch diameter and $\frac{7}{8}$ inch pitch; the longitudinal joints are double-riveted, the pitch-lines being $\frac{3}{4}$ inch apart, and the cylindrical joints are single-riveted. Each pipe is fitted with a welded and rolled socket shrunk on, riveted and caulked, the sockets being $3\frac{1}{2}$ inches in depth. Spigots are formed by welding the pipe-end to make it seamless, a welded ring 5 inches in width and $\frac{1}{8}$ inch in thickness being then shrunk on and secured by counter-sunk rivets. All seams have a tarred canvas insertion and were

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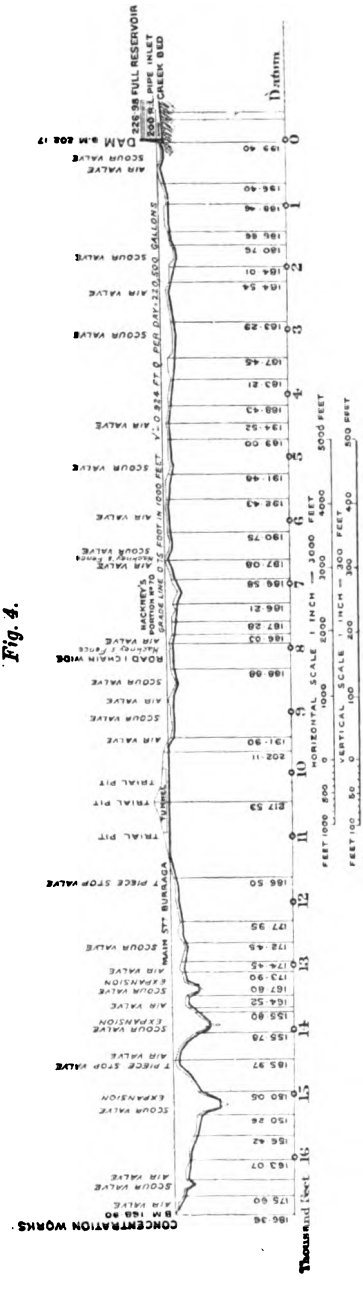

Fig. 4.

machine-riveted and caulked. The pipes were tested by hydraulic pressure to 200 lbs. per square inch and were then dipped in a hot bath containing a mixture of equal quantities of bitumen and distilled tar. The pipes are laid to regular gradients, and at all bends, horizontal and vertical, cast-iron pipes curved to 50 feet and 25 feet radius are inserted, and all joints, both in the steel and in the cast-iron pipes, are made with spun yarn gasket and run in with lead in the ordinary way. Across deep gullies the pipes are carried on concrete pillars, expansion-pieces being inserted at one end of the exposed pipe. Air-valves are provided at all summits, and scour-valves in all dips. At the end of the pipe-line a small storage-tank of 10,000 gallons capacity is provided, from which other tanks on the mine are supplied. The actual discharge by measurement was found to agree closely with the calculated delivery of 220,500 gallons per day for which the pipe was designed.

Cost.—The cost of the works, exclusive of the land, was £14,661, of which the dam cost £9,566 and the pipe-line £5,095. The land for the masonry dam and reservoir and part of the pipe-line was obtained from the Crown under the provisions of the Mining Act, but as part of

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the pipe-line passed through private lands, special arrangements had to be made with the proprietors for way-leave. In all cases, however, the conditions under which the land was obtained were very satisfactory. The following are the costs of the materials per cubic yard used in the concrete:—

Rubble Stone.

	s.	d.
Quarrying and explosives	4	6
Cartage (1 mile)	2	0
Total	6	6

Broken Stone (1½ inch and ½ inch).

	s.	d.
Quarrying and explosives	4	6
Cartage (1 mile)	2	0
Crushing	1	6
Total	8	0

Sand.

	s.	d.
Getting and carting 2 miles (no washing necessary)	4	9

Cement.

	£	s.	d.
Cost per cask weighing 3 cwt. 2 qr. 7 lbs.	0	11	6
Freight by rail 149 miles from port of Sydney	0	4	4½
„ „ road 42	0	5	4
Storage and handling	0	0	4½
Commission	0	0	1½
Total	1	1	8½

The work was carried out under contract by Mr. John Ahearn, of Sydney, from whose accounts the following particulars of net cost for the two classes of concrete have been compiled:—

	Per Cubic Yard. £	s.	d.
Cement	1	5	1½
Sand	0	2	3¼
Broken stone (½-inch gauge)	0	5	4¾
Timber and labour in fixing	0	2	6
Labour in mixing and laying	0	3	6
Net cost of plant, including erection, removal, and freight, after deducting proceeds of sale	0	0	11
Total	1	19	8½

1 : 2½ : 3½ concrete.

for which the contractor was paid £2 per cubic yard.

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	Per Cubic Yard. £	s.	d.
Cement	0	14	8
Sand	0	1	7
Broken stone (½-inch gauge)	0	4	6
Rubble plums	0	1	1½
Timber and labour in fixing	0	2	6
Labour in mixing and laying	0	3	6
Nett cost of plant, including erection, removal, and freight, after deducting proceeds of sale	0	0	11
Total	1	8	9½

1:3:5 concrete and rubble plums.

for which the contractor was paid £1 14*s.* 4½*d.* per cubic yard.

The Paper is accompanied by two drawings, from which the Figures in the text have been prepared.

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(*Paper No. 3375.*)

"Notes upon Municipal Work in Sydney, New South Wales."

By RICHARD WATKINS RICHARDS, M. Inst. C.E.

THE City of Sydney has an area of about 2,676 acres, is about 2½ miles in length and 2½ miles in breadth, and contains about 110 miles of streets. The population is estimated to be about 100,000 persons, and the rateable value of City properties about £2,000,000. Owing to the varied physical configuration of the land, and the consequent irregularity in the direction, width, and levels of most of the streets first constructed, probably in no other large city in Australasia are the difficulties of street construction so great as in Sydney; the authorities who controlled the affairs of the City in earlier days were met with problems in determining the most suitable levels and the best adaptable widths and directions of streets, and errors were established as far back as 1834 which have necessitated special legislation to remove and rectify them as recently as 1878 and 1889.

In a proclamation[1] dated 31 December, 1834, Essex Street was proclaimed 60 feet in width, with 12-foot footways and a 36-foot carriage-way; its width, however, varied between 50 feet and 56 feet, the footways being only 4 feet to 10 feet in width; and as recently as 1889 the City Council, in dealing with building alignments of this street, approached Parliament with a Bill to enable them to conform to the existing features. This Act provided for the street to be of a width varying between 27 feet 10 inches and 36 feet 4 inches in the carriage-ways, the width of the footways to be 10 feet. In the same notice Harrington Street was gazetted with a 36-foot carriage-way and 12-foot footways, the total width being gazetted as 40 feet, a difference of 20 feet in schedule. On the old plan laid before the Governor and Executive Council, dated 1834, Harrington Street, from Argyle Street to what is now Globe Street, is shown 60 feet in width. Its actual width varies between 38 feet and 48 feet, and it has been continued with

[1] *Vide* folio 9 of "Government Gazette," 1835.

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irregular widths and almost useless formation to Essex Street. These few instances of defective alignments will serve to show the many difficulties that have had to be overcome in obtaining uniformity of width, whilst directions were no doubt formerly decided by the courses of cleared tracks. As indicating the difficulties arising from differences of level, the following are levels on a section across a number of adjacent streets:—Kent Street North, at Flagstaff Hill, 67·72 feet (above high-water level); Upper Fore Street, 122·6 feet; Princes Street, 109 feet; Cumberland Street, 101 feet; and George Street, 21·35 feet. A little to the north of this assumed line of section is Argyle Street, with a maximum level of 54·37 feet above high-water level, leading to George Street. This awkward configuration necessitated the springing of masonry arches over Argyle Street at Princes Street, Cumberland Street and Gloucester Street. Again at West Sydney, Wattle Street, at Fig Street, is 3·6 feet above high-water level, whilst Fig Street 4 chains easterly, at Jones Street, is 54·8 feet above high-water level. East Sydney is not devoid of similar characteristics; Dowling Street, at Cowper Wharf, is 4·80 feet above high-water level; and, assuming a line of section to Victoria Street North, Brougham Street, 3·5 chains to the east, is 25 feet above high-water level, and Victoria Street, 3·5 chains farther east, is 96 feet above high-water level. To approach this part of East Sydney no less than three flights of steps, all within a distance of 12 chains, are constructed. These means of access entailed considerable expenditure, one of the largest retaining-walls in the city being erected here in concrete, under the supervision of the Author.

In dealing with the exceptional conditions, the Author from time to time recommended the resumption and re-subdivision of certain areas, such as that bounded by Kent Street on the west, the harbour on the north, George Street on the east, and Grosvenor Street on the south. The land and streets within these limits have been known as the "Rocks," and may be taken as the north-west corner of the city. The Council, however, did not act upon the suggestion, and (like most schemes for the advancement and improvement of the city) it was taken up by the State Government, and, at the time of writing, a Board especially constituted has devised a scheme for the reconstruction and remodelling of the streets and lands embraced. This Board is known as "The City of Sydney Improvement Advisory Board," and the work which it is proposed to carry out will, in the opinion of the Author, involve an expenditure of about £500,000. There are other areas

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within the city, not precisely similar in their constitution, which, in the interests of public health, need to be resumed and remodelled. The experience of cities of the Old World would tend to justify such a course, as the city would be reimbursed by selling the lands thus made available under improved conditions; the cost would be further provided for by a betterment tax. The Author has submitted for consideration proposals for five important city areas. The outbreak of bubonic plague led the Council to consider these, amongst other proposals, but efforts in this laudable direction lapsed. The Rocks resumption was then determined upon by the Government.

Street Construction.—Most of the central and main streets of the city are wood-paved. In this work different methods have been employed, depending on the conditions of traffic and the gradients. The first pavement was laid during the year 1880, under the supervision of Mr. A. C. Mountain, M. Inst. C.E., then City Surveyor. This was merely an experiment to determine the relative merits of the various timbers used. The blocks were of various classes of timbers, hard and soft woods, and were laid upon a foundation of 6 inches thickness of concrete. The joints between the blocks were 1 inch in width, and the interstices were grouted and well rammed with tarred screenings. This work was continued during a period of 6 years, the results proving that the hardwoods of New South Wales, of northern growth, are the best and most suitable woods for carriage-way pavements, and that the narrower the joint the better will be the pavement. Consequently black butt, tallow-wood, blue gum, and red gum were always used, and the joints of the pavement were reduced in 1886 to $\frac{3}{8}$ inch in width. These results were so satisfactory that the Author, early in 1888, adopted close or slape joint for pavements, selecting a roadway with a gradient of about 1 in 100, the transverse section being laid with a cross-fall of 1 in 60 from the centre of the roadway to the water-tables, and the after condition of this work justified the continuance of the method wherever gradients permitted. The blocks measure 9 inches by 6 inches by 3 inches, and are thoroughly seasoned. The foundation consists in most cases of 6 inches of concrete floated in cement-mortar, gauged 2 of sand to 1 of cement. In one or two instances, on account of the ground being spongy or the traffic heavy, the thickness of the concrete was increased to 9 inches. It may be thought that expansion would be increased under these conditions, but it was not so; in fact, expansion was less. The most effective method employed to resist expansion was that of laying planks, 6 inches by 3 inches, in

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lengths of 10 feet to 20 feet, on edge, against the curb to the full depth of the wood blocks, each length breaking joint evenly with the plank opposite on the other side of the road. After some years a pavement so laid has not required attention, notwithstanding the variable climatic influences to which the country is subjected. Another method adopted with success was to lay the blocks longitudinally, *i.e.*, parallel to the direction of traffic. On even gradients, blocks so laid have well maintained their position; the foothold is good and expansion is practically *nil*. The steepest gradient wood-paved is 1 in 13, for a distance of a few chains only, but the Author is of opinion that blocks should not be laid on gradients steeper than 1 in 18, and where the gradient is not less than 1 in 50 the roadway should be laid with a transverse fall from the centre to the water-tables of 1 in 60 or 1 in 80. Much advantage results from dipping the blocks in boiling tar and pitch mixed in the ratio of 2 to 1, sufficient time being allowed to drain off superfluous dressing before the blocks are laid in the work. Care should also be taken to hammer and wedge the blocks thoroughly close at every ninth or twelfth row.

The pavements laid with wide joints have from time to time been removed, the old blocks being cleansed and cut down to depths of 4½ inches and 5 inches. The cleaning was done by scraping the blocks and dipping them into boiling water to which potash had been added, after which the adhering pitch, tar, and screenings were easily removed by scraping them with a steel blade; the block was then cut to one or other of the sizes mentioned. The average cost of this treatment for about ¾ million blocks was a little more than 19*s*. per thousand. The 5-inch blocks have been relaid in central streets, and give a pavement almost equal to one composed of new blocks. The 4½-inch blocks are used for paving narrow and less important roadways.

The hardwoods of New South Wales are now extensively employed for street-paving, not only in Australasia, but also in Europe and in America, and it is readily agreed by experts that a close-jointed New South Wales hardwood pavement gives as even and smooth a surface as asphalt, and is less costly to maintain.

With reference to asphalt it may be mentioned that many efforts have been made to introduce this class of pavement into Sydney, but only in a few instances have the proposals been accepted. As far back as 1880, simultaneously with the laying of the first wood-pavement, an experimental area was laid with asphalt blocks, but the results were very unsatisfactory. The subject was revived in 1886, and a trial pavement was laid with

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asphalt blocks, but was removed after being completely worn out, and replaced with hardwood blocks. More recently a few asphalt blocks were laid in juxtaposition to wood blocks, but after a few weeks they became pulverized by the heavy and continual traffic. Sheet asphalt has also been laid in two instances; in one, after a very short period, it was found that the heat and traffic conditions caused it to become plastic and to work itself to the sides of the roadway, laying bare the wood blocks upon which it had been laid; these results were followed by abandonment of its use, until the year 1900, when sheet asphalt was laid upon wood pavement subjected chiefly to carriage traffic. This pavement, so far, has worn better and has given more satisfaction than any other of a similar nature, and the Author is inclined to the opinion that, other things being equal, more particularly as to cost of laying, maintenance, etc., sheet asphalt will yet take its place in some of the Australian cities, especially those remote from forest growths of hardwood. While in Auckland early in 1902 the Author observed that a large contract was in progress for laying the tram-track and roadway of Queen Street with sheet asphalt. This work was determined upon after much debate and consideration by the local authorities of that city, and may be taken as an index of the enterprise which characterises the municipal administration of the cities of New Zealand.

The methods employed in constructing macadamised roadways are so well known that it is perhaps unnecessary to describe those practised in Sydney; but, as there has been at all times diversity of opinion as to whether spalls or pitchers are better for ballasting, it may be mentioned that the Author's experience has led to a preference for pitchers of 9 inches to 14 inches in length, 9 inches in depth, 7 inches in width at the top and 9 inches in width at the bottom, laid as far as possible on their natural bed, all interstices being filled in with spalls before receiving the metal. In roadways so laid and where the wearing surface of metal has worn to such an extent as to throw the traffic directly on to the ballast, for months the pitchers held sound and fit to take another sheet of metal, whereas spalls under similar conditions crumbled and pulverized, necessitating the work of reballasting.

In all cities where chiefly paved roadways have been constructed, it is imperative that the width of tires should be regulated; otherwise the action of traffic will have a very deleterious effect on the wearing surfaces. In some cities it is provided that, "The front axle shall be shorter than the rear axle by twice the width of the tire prescribed for such vehicles. Any omnibus

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running on streets paved with asphaltum on any portion of its route shall be provided with flat tires of width as follows:—For omnibuses weighing loaded 4,000 lbs. and not exceeding 5,000 lbs., 2½ inches; for omnibuses weighing 5,000 lbs. and not exceeding 6,000 lbs., 3 inches; for omnibuses weighing 6,000 lbs. and not exceeding 7,000 lbs., 3½ inches, and for omnibuses weighing loaded 7,000 lbs. and upwards, 4 inches. Violation of this provision subjects the offending person, firm, or corporation to a fine or penalty for each and every offence, to be collected and paid into the city treasury for the use of the city." In Sydney the average weight of a two-horse omnibus loaded is 5,376 lbs. and that of a four-horse omnibus loaded is 7,392 lbs. The time has arrived for local authorities to proceed to acquire, if not already held, the powers necessary for controlling traffic and enforcing regulations as to width of tires and such other conditions affecting the stability, durability, etc., of roadways.

Disposal of Refuse.—The disposal and treatment of refuse have engaged close attention, more especially since the first outbreak of bubonic plague, but long previously (since 1889) the question of burning the refuse was more or less under consideration. Various proposals were made prior to 1896 for the erection and working of refuse-destructors by English, American, and local manufacturers; and, after years of inquiry by special committees, the Council, late in 1896, commissioned the Author to visit English and European cities to inquire into and report upon the best means in operation abroad, and to submit a scheme for the treatment of the refuse of Sydney. A report and scheme were submitted in September, 1897, but it was not until the recrudescence of the plague in 1901 that the recommendation of the Author was adopted and a contract entered into for the erection of a six-cell refuse-destructor, etc., of the "Perfectus" type by Messrs. Goddard, Massey and Warner. The delay was caused by the desire to have a destructor of local make and design, and by the sanitary authorities (engineers and medical men) being at variance as to the necessity of introducing destructors, some favouring the trenching and covering of the refuse on waste lands—a practice followed in some Australian cities, and at one time viewed with favour in Sydney. Meanwhile the refuse was tipped in swampy ground on a common area in South Sydney adjacent to populated districts, and was covered with 6 inches of sand removed from hills near by. This method had many advocates amongst the authorities and others, although its cost was almost equal to that estimated for treatment by fire. The destructor has now been completed, and consists of six

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cells, with a chimney-shaft of sufficient capacity to admit of six additional cells being installed. The present installation is capable of treating 60 tons per day of 24 hours, working in three shifts, or a quantity equal to one-fourth of the total collected. Although the term of working and maintenance has not yet expired, the destructor has treated a little over 60 tons per day.

The plant comprises two tubular boilers, a steam-engine for driving the mills and general machinery, a donkey-pump for feeding the boilers, a vertical engine for driving the fans, a blowing-fan, a tank of 1,000 gallons capacity, an improved mortar-mill for grinding clinker for mortar, a mill for breaking clinker suitable for converting into flags for paving footways, and a small plant for the electric lighting of the works. The cost of the work was a little more than £10,000. Attached to the destructor is a lethal chamber for the destruction of diseased and stray dogs, similar to that in operation at Battersea, as well as a disinfecting chamber for bedding, etc. A recent trial of these contrivances in the presence of the City Health Officer and others was attended with very satisfactory results. The destructor is being worked by the contractors for a term of 6 months, and has recently treated the required quantity of 60 tons per day. The clinker is suitable, after grinding, for the making of paving-slabs.

The City of Sydney is also governed by the Metropolitan Water and Sewerage Board, having control of the water-supply and sewerage of the city; the Australian Gas-light Company, for street-lighting; and the Sydney and Suburban Hydraulic Power Company; the tramways, electric, steam and cable roads which thread the main streets, are worked, controlled, and maintained by the State. It may be mentioned that the Sydney Municipal Council has recently accepted the tender of an English firm, in accordance with the report and recommendation of Sir W. H. Preece and Major Cardew, for the lighting of the city by electricity, and at the time of writing a Select Committee of the State Parliament is taking evidence with a view to legislation for the establishment and government of a Greater Sydney, to vest in one body the control of all the services mentioned in the foregoing. The need for reform in municipal government in Sydney has long been recognised, and the strenuous efforts being made in this direction will no doubt result in legislation for the better government and municipalization of the services of the City of Sydney and its suburbs.

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(*Paper No. 3378.*)

"Recent Developments of the Asphalt Industry."

By WILLIAM HENRY DELANO, Assoc. Inst. C.E.

SINCE 1880, when a Paper[1] by the Author on "The Use of Asphalt and Mineral Bitumen in Engineering" was read before a meeting of the Institution, the employment of the material has so largely increased that it may be worth while to take a retrospective view, and a glance into the future of this industry, in which so much British capital is invested, and the development of which gives employment to so many engineers.

Asphalt is a natural product, and consists of limestone impregnated with pure mineral bitumen. Its ideal composition is 80 per cent. to 90 per cent. of pure carbonate of lime, and 10 per cent. to 20 per cent. of pure mineral bitumen. Bitumen is natural mineral pitch, composed of 85 per cent. of carbon, 12 per cent. of hydrogen and 3 per cent. of oxygen. It is only found pure in the rock which it permeated when in a state of vapour, and under enormous pressure. The recent eruption of Mount Pelée, in Martinique, affords evidence of the great heat and pressure caused by the combustion of bituminous vapours. Mineral bitumen should not be confounded with the residuum of crude petroleum, naphtha, shale, or animal fats, nor, above all, with gas-tars: these contain dyes, which natural bitumen does not. As asphalt and bitumen are natural products, they vary in quality and must be taken as Nature produces them. Thus the limestone in the Sicilian variety of asphalt is of coarse grain; but in Seyssel, Val de Travers and Servas asphalts the grain is fine, so that the specific gravity of Sicilian asphalt is less than that of the other rocks named. The bitumen contained in Seyssel and Sicilian asphalts is solid and tough, whereas that contained in Val de Travers asphalt is oily.

The Author, having experienced much trouble due to waves and buckling in roadways of Val de Travers asphalt under heavy traffic and exposure to hot suns, consulted the late Mr. Schützen-

[1] Minutes of Proceedings Inst. C.E., vol. lx. p. 249.

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berger, Professor of Chemistry at the Collège de France, who had made a special study of hydro-carbons. This eminent chemist, after separating the bitumen from the pulverized rock by dissolving it in carbon di-sulphide and filtering the solution, heated the bitumen *in vacuo* without obtaining any appreciable evaporation; when the heat was increased the bitumen decomposed. This showed that the oil could not be got rid of by heat, and led the Author to blend Seyssel with Val de Travers, and subsequently with Servas rock, with satisfactory results. By blending, asphalt powder for roadways can be obtained suitable for tropical or temperate climates.

The molecules of natural asphalt are held together, not by cohesion, but by bituminous agglutination. Mr. Léon Malo found that the test for asphalt is to heat a small piece on a hot iron plate, when it will fall to pieces. To test its compressibility, a small hydraulic press with appropriate moulds, or a tube with a plug and hammer, may be used. Some asphalts, after being subjected to a pressure of 6 tons per square inch, will crumble under pressure of the fingers. The unimpregnated limestone found in an asphalt mine will not crumble on being heated.

Asphalt mastic is composed of asphalt powder and refined bitumen, mixed mechanically in a boiler under heat. The mixture, after being heated to, say, 400° F., is run into moulds, the blocks weighing about 56 lbs. It should contain about 15 per cent. of bitumen, native and added, and will not fall to pieces on being heated, as asphalt rock does, nor will it compress. Mr. Malo has pointed out that in a layer of compressed asphalt the top of the layer is always denser than the bottom, even when the thickness has been reduced by wear to ½ inch. The surface, therefore, always rests on a cushion. To make good mastic, care and experience are required. It must be made of blended rocks, ground very fine, mixed with refined bitumen and thoroughly cooked; it cannot be too pure. For footpaths, grit is added to it, say, 33 per cent. for temperate, and 50 per cent. for tropical climates. Clay, pyrites and vegetable matter are all detrimental, whilst taking up the place of good material. The qualities of asphalt, bitumen, and their product, mastic, are remarkable, and are daily being more and more appreciated in engineering work.

Asphalt makes noiseless roadways, is impervious to water, and produces no dust or mud; mastic makes footpaths like a carpet, arrests capillarity, is air-, water- and vermin-proof, absorbs vibration and is a non-conductor of electricity. By mixing bitumen with pure silex, a mastic can be made which resists acids.

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The Island of Sicily alone now produces annually 75,000 tons of natural asphalt, sufficient to lay 812,000 square yards of compressed asphalt, 2 inches in thickness; whilst the output of the other mines in Europe (Seyssel, Val de Travers, Chieti in the Abruzzi, Limmer, Vorwohle, Lobsann, Auvergne and Syzrane in Russia) may be estimated at 120,000 tons annually; whereas previously to 1870 the Seyssel and Val de Travers mines were the only ones of repute, and their combined annual output was about 50,000 tons. When in the United States some 5 years ago, the Author noticed that one American Company, managed by a Colonel of Engineers, had an army of 18,000 men employed daily in laying bituminous compounds for roadways in different towns of the Union. Often the process followed was to construct the roads first, and to build the towns afterwards; where money was not available, payments were effected in bonds on land, or even on produce. The Author's experience has been acquired chiefly in France, where the asphalt industry originated, and where the special plant and tools, now used everywhere, were invented and elaborated.

In 1872 the Author was called upon to undertake the management of the original Asphalt Company, which had the contract for all the compressed asphalt roadways for the town of Paris. These roadways were then being laid on hydraulic-lime concrete, only 4 inches in thickness—actually the same thickness as for footpaths—and of this ½ inch thickness consisted of a mortar floating, spread upon the concrete after it had been laid, which crumbled under the blows of the rammers used in ramming the hot asphalt-powder to make the road. On the Author's recommendation, Portland-cement concrete was laid, at the Company's expense, in the Rue d'Antin, and this work stands to the present day; the old streets, however, were all laid on lime concrete. Some of the engineers of the town of Paris who had the superintendence of the works declined to have Portland-cement concrete at any cost, and at the end of 5 years, when the concrete wore out, the Company had lost £40,000, owing to the onerous conditions of the maintenance contract, by which they were paid 1 franc per square metre per annum for all repairs, including the re-laying of one-tenth of the surface annually and setting the whole in order at the end of the contract. When holes in the asphalt had to be repaired, the crumbling concrete had to be re-laid also, but, owing to the exigencies of traffic, it had not sufficient time to set, so that work was carried out under grave difficulties; and in rainy weather, in order to get a dry surface for the hot powder, it was

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necessary to use bituminous concrete, or at least a layer of liquid asphalt.

In general, yielding materials like asphalt require a rigid and resisting concrete, and floating is undesirable. Finding how detrimental to the asphalt roads was the greasy mud brought from macadam and stone pitching, the Author presented the town of Paris with one hundred india-rubber squeegees, and this led to the adoption and manufacture of these tools in France. He also designed a special form of water-cart for cleaning asphalt roadways, the sprinkling being effected in front of the horses, as well as behind them, the French plan of flushing with a fireman's hose and nozzle being impracticable in narrow streets or in windy weather. The extreme gradient for an asphalt roadway is 1 in 30, and the camber between the outside edge of the gutter and the crown of the road should not present gradients of more than 1 in 50.

In 1884 the town of Paris made a 10-years' contract with the Author's Company, by which they agreed to pay, for a 2-inch layer of compressed asphalt, 14 francs per square metre (9*s.* 4*d.* per square yard) and for a 6-inch layer of Portland-cement concrete 5½ francs per square metre (3*s.* 8*d.* per square yard), and for maintenance 2 francs per square metre (1*s.* 4*d.* per square yard) per annum, with the undertaking that all the streets laid with lime concretes should be re-laid with Portland-cement concrete, the town paying for the repairs on those streets apart, until the substitution should take place. It was in 1884 that Sicilian asphalt was accepted for the first time, the Paris Engineers having been commissioned to visit and report on every asphalt mine then known, and it took the place of St. Jean de Marvejols asphalt, being cheaper. A branch of the London Limmer Asphalt Company obtained the contract for about one-third of Paris, but afterwards passed over their contract to a French company, formed by the Neuchatel Company, Limited, which holds the concession for the Val de Travers mines, who had not renewed their concession to the Author's Company. It is notable that English capital had absorbed the asphalt industry originated in France, and led to its development all over the world.

The town of Paris allowed the contractor to grind up the pieces of old compressed asphalt from gas trenches and repairs, and to convert it into mastic for the liquid gritted asphalt footpaths; but it would not allow the old gritted mastic from the footpaths to be used again for new works or re-layings; this could only be used for small repairs and trenches, and even then only if mixed with an equal quantity of new material. The area of the asphalt

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mastic footpaths in Paris is about 6,000,000 square yards; this material provides a surface which is less fatiguing to walk on, and much more agreeable to the sensitive human foot, than granite, stone, or hard cement. The town paid 35 centimes per square metre (2·8*d.* per square yard) per annum for the maintenance of the footpaths, laid 15 millimetres ($\frac{9}{16}$ inch) in thickness, for all repairs arising from wear and tear, including the re-laying of one-fifteenth part of the entire surface every year, whether wanted or not. The thickness of the layer being 15 millimetres, and the wear of the surface being estimated at 1 millimetre per annum, it was supposed that at the end of 15 years the whole surface would be re-laid. In practice, however, it was found that the narrow streets in the centre of the town wore out in 5, 6, or 10 years, owing to the heavy traffic, whereas those in the suburbs were as good at the end of 15 years as on the day they were laid. Knowing that old mastic, remelted with fresh bitumen (the main ingredient of asphalt), is just as good as, if not better than, new mastic, owing to the second fusion, the Author proposed to lay all surfaces 20 millimetres ($\frac{3}{4}$ inch) thick, instead of 15 millimetres ($\frac{9}{16}$ inch), using a mixture of equal quantities of old and new mastic, already admitted for repairs and trenches, and to suppress the obligation to re-lay one-fifteenth part of the surface annually, only re-laying what was necessary, thus saving annoyance to householders and unnecessary carting, whilst the contractor got rid of materials easily that otherwise he had to sell to suburban corporations, private undertakings, etc. The proposal was agreed to, and this arrangement has been continued ever since, to the general advantage of all concerned. The concrete used with compressed asphalt prepared in this way is composed of washed flint pebbles, river sand, and best Portland cement, gauged 4, 3 and 1. The cement, not more than 2 months old, is first turned over dry, then mixed wet, being sprinkled just enough to hydrate it. No floating is required. A level surface is obtained by using a straight-edge and smoothing the mass with a flat rectangular shovel, filling up any cavities with a little mortar, composed of 3 of sand and 1 of cement, mixed on the spot. By this plan the whole mass sets at the same time, which is absolutely necessary for hot asphalt-powder, whereas for wood or cold asphalt slabs this is not necessary. It is well to allow 5 days for setting in summer, or 7 days in winter, and the surface must be dry, otherwise the powder, heated to 300° F., would convert any moisture into steam, which, in passing through the asphalt, would give rise to nodules. For liquid-asphalt footpaths, hydraulic-lime concrete may be used,

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and a mortar floating, in order to get a true surface with a straight-edge, and to prevent more asphalt being laid than the thickness warrants. A $\frac{3}{4}$-inch layer weighs 80 lbs. to the square yard.

Perhaps the best method of protecting any work in masonry, or iron vaults, roofs, reservoirs, etc., is by means of two layers of pure asphalt, $\frac{2}{5}$ inch in thickness, superposed, the joints of the first layer being covered; a recess can be cut into the masonry and the fillet pressed in. Such a layer will weigh about 68 lbs. per square yard. A damp-course laid in walls of buildings, at a level of about 1 foot above the ground, will stop capillarity and preserve the buildings from the action of water and frost. To keep out damp is as much a necessity of hygiene as good drainage. The Egyptian Sphinx, the Pyramids, and so many tombs and buildings, not to mention more recent Roman buildings in Africa, have survived mainly because the chief elements of decay, water and frost, are absent; if such constructions had been in England, the expansion caused by frost and the contraction caused by thaw would speedily have disintegrated them. In many brick and stone railway-arches in Paris, water drips through the joints after prolonged rain. The Pont du Jour, a stone viaduct over the Seine at Auteuil, is full of water in rainy weather, and from certain joints water runs out as from a spring. Mr. Barabant, the Manager of the Eastern Railway of France, who, as Ordinary Engineer, and subsequently as Chief Engineer, of the town of Paris, had special opportunities of studying asphalt—having had the Municipal Laboratory under his charge—has had all the bridges and viaducts on the ordinary and strategic lines between Paris and the frontier laid with pure asphalt coating, and has had the platforms of the Paris and Nancy stations laid in compressed asphalt slabs and powder. The Paris Lyons and Mediterranean, Orleans, Midi, North and West Railway Companies have largely used Seyssel asphalt for platforms, bridges, viaducts, etc.

It has been abundantly proved that asphalt mastic is unaffected by cold or heat, *i.e.*, expansion and contraction do not alter its qualities. The late Captain Coignet had some of the Seyssel asphalt coating from the bomb-proof casemates of the Donjon of Vincennes taken up, after lying entombed since 1833, and found that no change had taken place in the asphalt. A root of lucerne, 5 to 6 yards in length, had tried in vain to penetrate the layer. Asphalt has the defects of its qualities, for in foggy weather the moisture in the atmosphere will condense on the asphalted surface of the casemates, and must be swabbed off. This is better than

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letting it soak into an ordinary soil. But, for this reason, in asphalted railway-stations, flour, cement and lime must be kept off the ground by wooden frames. The gradual disintegration of walls and floors is sometimes traceable to the ravages of rats and mice; they will nibble through concrete, but they leave asphalt alone. Being a non-fermenting and non-decaying material, it affords no home to insects. A floor laid on joists fixed on liquid asphalt is safe from vermin, and there need not be any appreciable space between the asphalt coating and the upper flooring. In the case of fire, asphalt keeps out the air, and holds water; when the wood-work below it has been burned away, it will fall like a wet blanket on the flames and extinguish them. This quality was proved by the experiments made by the Omnibus and Cab Companies in Paris, with the result that the floors of granaries and silos, wash-houses, stables and mangers are now generally coated with liquid asphalt. It was found by Messrs. Tourtel Frères, of Tantonville, near Nancy, that whereas gas tar gave a disagreeable flavour to malt, natural asphalt was absolutely neutral; this has led to its adoption for flooring in many breweries and maltings. Slabs of asphalt of various sizes and thicknesses, made in a hydraulic press, are now manufactured largely and sent to all parts of the world. They are laid on Portland-cement concrete similarly to asphalt powder, but are fixed in a wet layer of pure Portland-cement mortar; after being laid, cement grout is poured into the scarcely-perceptible joints, and swept off with saw-dust when dry. These slabs stand well in streets and courtyards where there is little traffic, and require no costly plant, as does powder; they can be laid on wet concrete, but, as they have attained their ultimate compression, wear begins at once.

A method of laying asphalt powder cold, by mixing it with petroleum essence and a solution of india-rubber, which softens the bitumen contained in the rock and so facilitates compression, the petroleum afterwards evaporating, has been recently employed in Marseilles, Antibes, Barcelona, Aix-les-Bains, Toulon, Nice and St. Etienne. By this process work can be done in rainy weather.

Just as plasterers mix cow-hair with their plaster, and as cement is strengthened by iron wire and rods to give it tenacity under strain, so liquid asphalt can be treated for making tanks, pipes, conduits, reservoirs, etc. Asphalt, and india-rubber, of which it is a counterpart, are both hydro-carbons, having the same ingredients. Asphalt has little resisting power in itself, but it can be laid on a hempen sheet or thick paper, to give it more tenacity as when laid upon a wood flooring. When liquid asphalt is used

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for the inside lining of a reservoir, vertically, a layer of brick should be laid in front of it as the work proceeds, to keep it up. In Germany, cement tanks for holding molasses are now being replaced by asphalt, which does not crack. Bitumen resists alkalies and acids, so that by mixing it with pure silex in powder, or with pulverized basalt, a mastic or paste can be made which can be applied like ordinary mastic for accumulator-rooms, baths for electrolysis, etc.; numerous special applications of this material have been made for the Electric Traction Company at Paris, Lyons, and elsewhere. It has been found that the large Portland-cement-concrete blocks used in connection with breakwaters and piers to arrest the force of the waves, become disintegrated by the action of the magnesia in the sea-water, as well as by the boring propensities of numerous marine animals. The blocks may be protected by an application of liquid asphalt, say $\frac{9}{16}$ inch thick, upon each side of the cube, carefully jointed at the angles, and the remedy, though expensive, is sure. Asphalt flags are made by running mastic in shallow moulds on a true-planed cast-iron slab; they are laid on a concrete base, the joints being run with a little special mastic, heated in an iron basin and spread with an iron tool. At the works of the Compagnie Générale des Asphaltes de France, the strong-room is made of bituminous concrete, and is absolutely fire-proof. Pipes and tubes can be made for the carrying of telegraph-, telephone- or power-wires. Bitumen resists the corrosive action of acetylene-gas on iron pipes; and in Paris, water-pipes are coated with a layer of mastic before being laid in the ground, thus preventing external corrosion.

The chief application of asphalt to which the Author desires to direct attention in this Paper, however, is its use as a material for absorbing vibration, either caused by the passage of trains and heavy vehicles, or by percussion, like that of the steam-hammer, and also as a foundation for heavy ordnance in forts. Mr. Malo, at the Seyssel mines, first experimented on these materials, and his lead has been followed up by the Author. The material used may be either bituminous concrete, or asphaltic powder, as used for roadways; the powder, however, must be rammed in successive layers in a suitable case or box, made of steel or wrought iron, to support and maintain it, and the layer, instead of being 2 inches thick, is 8 inches to 1 foot in thickness. Asphaltic powder is used chiefly for foundations for steam-hammers, the bed-plate fitting on to the asphaltic mass. There are numerous examples of its use, and no failure has been recorded. In the year 1872 the Author had at work a Carr disintegrator, making 700 revolutions per

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minute, for grinding rock-asphalt, the axles being supported on stout oak bearings. The vibration transmitted through the soil was such that it was quite impossible to write within 600 feet of the machine. Being threatened with a law-suit, he resolved to put down bituminous concrete foundations for the bearings, and to surround the pit in which the machine worked by a wall of the same material. When the work was completed, no one could tell in the adjoining workshops and warehouses whether the machine was working or not, and a glass of water placed on the bituminous concrete wall showed no ripples. For 30 years, during which at least 5,000,000 tons of asphalt have been ground to fine powder, no repairs have been necessary. One of the more notable applications was made by the Orleans Railway in their underground railway between the Place Denfert-Rocherèau and the Port Royal, where the line passed by the Paris Observatory. Admiral Mouchez, who was then Chief of the Observatory, feared that his mercury bath for daylight observations would be shaken, and a foundation consisting of 633 cubic yards of bituminous concrete was therefore laid under the rails in 1894. The trains have run over it ever since, and no repairs have been found necessary. In the premises of the famous firm of Moët and Chandon, who keep a stock of 8,000,000 bottles of champagne in the cellars, it was feared that the machinery laid down for the electric lighting of their 8 miles of cellaring, would shake the wine, and in 1888 the Author put down 21 cubic yards of bituminous concrete, with a most satisfactory result. In 1892, the machinery being increased, the Author laid down an additional 17 cubic yards. In the Author's opinion, the vibration on the Central London Railway would be absolutely arrested by laying the rails on a foundation of bituminous concrete. Of course, the train service would have to be stopped, but a great deal might be done in the night at bad places.

For iron bridges over which, or under which, trains pass, this material is invaluable. Where a Portland-cement concrete will crack like mosaic, this material will stand. The Author has proved this in many cases, notably at an iron tubular bridge over the Seine at Elbeuf; at the Pont de l'Aqueduc, in Paris; and at the railway bridge over the Ceinture, or Girdle Railway, at Courcelles. At many forts round the French coast the very heavy pivot-guns are mounted on foundations of bituminous concrete, which absorbs the vibration produced by a heavy discharge. The Author has also used a coating of asphalt mastic in the granite embrasures of forts to counteract the splintering caused by the impact of small shells.

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During the Commune of Paris, in 1871, the works of the Author's Company at the Quai de Valmy were under fire, and bullets which struck a heap of asphalt powder were flattened out. This led to the coating of iron turrets with asphalt. The late General Boulanger, when Minister of War, arranged with the Author to build a block of 390 cubic yards of bituminous concrete at the Polygon of Bourges, to test the effect of melinite shell, similar blocks being made of Portland-cement concrete and hydraulic-lime concrete. The whole was surrounded by a wall of unmortared stones. Melinite shells, 4 feet 3 inches in length by 1 foot 1¾ inch in diameter, with chrome-steel points, were fired at these masses. The result was that the cement- and lime-concrete blocks were pulverized; the bituminous concrete was not pulverized, but was torn asunder.

The chief asphalt mine in Europe is the Seyssel mine, the largest in France. It stretches from Seyssel to Bellegarde in the synclinal basin of the Rhône, which flows through the Department Ain on the east, and the Haute Savoie on the west. It is 10 miles in length and a little more than 3 miles in width, and its superficial area is about 20 square miles.

The bitumen which binds the soft lime oolite in this mine to form asphalt must have impregnated the limestone in a state of vapour, as is proved by the smoky appearance in the unimpregnated rock at Seyssel. The occurrence of bitumen in Trinidad, Venezuela, Cuba, and Mexico, on the surface of the earth, in its viscous state, just as it can be extracted from asphalt rock, would therefore appear to be due to the bituminous vapours having, at some depth, met with some porous rock like sandstone, through which they filtered upwards.

In Europe, the country that has taken the lead in laying compressed asphalt undoubtedly is Germany. There is more compressed asphalt paving in Berlin than in England and France together, there being about 2½ million square yards, all laid on Portland-cement concrete, 8 inches in thickness. These magnificent roadways are one of the features of Berlin, and give it an aspect of brightness and cleanliness unknown to other European towns. The Germans have studied asphalt synthetically, and have produced sundry imitations. An artificial asphalt, composed of limestone and bitumen, introduced by Professor Dietrich, of Berlin, was laid in König-strasse, Berlin, but was afterwards replaced; a mixture of Vorwohle asphalt and bitumen is used to a considerable extent. These mixtures are, perhaps, cheaper than natural asphalt, since, being made on the spot, the cost of railway carriage

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from the mines is eliminated; but they are inferior to natural asphalt, and with heavy traffic the surface has to be frequently repaired. German contractors have followed the English lead, and have bought mines in Chieti in the Abruzzi, in Italy, and in Venezuela.

In conclusion, the Author is of opinion that English municipalities can borrow money so cheaply that it is not worth while to forego the advantages of hygienic streets, in asphalt, liquid and compressed.

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(*Paper No. 3363.*)

"The Cauvery Power-Transmission Scheme."

By HAROLD THORNTHWAITE HINCKS, Assoc. M. Inst. C.E.

IN 1898 Captain A. Joly de Lotbiniere, R.E., whose services had been loaned to the Public Works Department of Mysore State by the Government of India, conceived the idea of applying the power of the Cauvery Falls to operate the mining machinery on the Kolar Gold Fields, at a distance of over 90 miles, by transmitting it electrically, all projects for utilizing the power in the vicinity of the falls being considered impracticable, owing to the inaccessibility and unhealthiness of the situation.

On receiving Captain Lotbiniere's Report, the Government of Mysore took action in the matter and obtained the sanction of the Government of India to the scheme, the first of its kind in India and probably in the whole of Asia. The greater part of the river at the site of the falls being in the Madras Province, the Madras Government granted their water-rights to the Mysore Government at a nominal charge for a period of 30 years. The Mysore Government also obtained a conditional contract to supply power to the mines of the Kolar Gold Fields, under the management of Messrs. John Taylor and Sons, of London, for 10 years. Captain Lotbiniere was then commissioned to visit and report on many of the large electric-power schemes in Europe and in America, and to consult with an advisory committee in London, consisting of Professor George Forbes, M. Inst. C.E., as electrical expert, Professor W. C. Unwin, M. Inst. C.E., as hydraulic expert, and Captain Jocelyn Thomson, of the Home Office, as secretary. The contract for the whole of the electrical plant was let to the General Electric Company of America, and that for the hydraulic plant to Messrs. Escher Wyss and Company, of Zurich. The Government of Mysore undertook to supply all wood poles and cross-arms, buildings and excavations, and all unskilled (coolie) labour, under the direction and supervision of the contractors.

The most important consideration in the whole undertaking is

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whether the water-supply will be sufficient in the dry season, lasting from about the middle of March to the middle of June, to give the turbines the 181 cubic feet of water per second which, it is estimated, will be required to provide 4,000 horse-power at the Kolar Gold Fields. At all other times during the year many thousand horse-power could be generated, but it is essential to the working of the mines that they should have a dependable and continuous supply of power. The mining companies, at the end of the first working year, have the option of indenting for an additional 4,000 horse-power. Taking this into consideration, the Government of Mysore have issued notices that they intend in cases of urgency to dam all irrigation-canals fed by the River Cauvery in their territory above the falls.

Water is taken from the River Cauvery about 2 miles above the falls, and is carried in two canals, 3⅓ miles in length, to three penstocks, each of which feeds two turbines in the generator-house. The turbines require 181 cubic feet of water per second, with an effective head of 387 feet 7 inches, to supply 5,970 horse-power to the generators, which produce current at 2,200 volts. The current is carried to the step-up transformer-station, which is in a higher and more healthy spot than the generator-station, and is here transformed up to 30,000 volts for transmission along the lines, which are in duplicate, to the step-down transformer-station, 91⅓ miles distant, on the Kolar Gold Fields. On being transformed down to 2,300 volts the current is distributed to thirty-one motors, ranging in size between 5 HP. and 400 HP., at distances of ½ mile to 3½ miles from the transformer-station. For all the motors under 100 HP. the current is further transformed down to 230 volts. The motors operate twelve air-compressors, eleven stamp-mill batteries, two quartz-dressing plants, five hoists and one pump, the aggregate capacity of which is 4,185 horse-power.

The River Cauvery.—The Cauvery is the most important river in the Mysore State. It rises in the Western Ghâts in the British Province of Coorg, and reaches the Mysore State at Fraserpet. For a distance of 20 miles it forms the boundary between Mysore State and Coorg, and then runs through the former for about 150 miles. The falls, where the generating-station is situated, are 45 miles below Seringapatam, and 92 miles from the distributing-station on the Kolar Gold Fields. There are really two falls, as the river is divided up by the island of Sivasmudram, which is in the Madras Presidency. A low dam has been made at the head of the eastern branch, to divert all water in dry weather to the

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western branch, but not high enough to divert flood-water. The sheer drop of water at the falls on the western branch is only about 180 feet, but, allowing for the minor falls and rapids above and below, a head of 406 feet is found to be available.

Canals.—About ¾ mile below the head of the western branch, another low dam has been constructed across the river, similar to that already mentioned. This dam is for the purpose of diverting the water required, through sluice-gates into the two canals leading to the penstocks on the bluff above the generating-station. As each one of these canals is sufficient to convey the 181 cubic feet per second required for present needs, one can be shut off at any time for cleaning or repairs. The canals have a width of 18 feet on the bed in earth cuttings, and the banks, which have a slope of 1 to 1, are dressed with broken stones for a thickness of 1 foot. In the construction of the canals a considerable number of rock-cuttings have had to be made, and in these the cross-section has been reduced to 12 feet in width, with perpendicular walls. In the earth-cuttings the canal-bed has a drop of 1 in 5,000, and in the rock-cuttings, to allow for the smaller cross-section, the gradient is 3 in 5,000. The total fall of level in the length of the canals is 4 feet 6 inches. The rate of flow of water in the earth sections will be 2¼ feet per second, and in the rock sections 4¼ feet per second. Unfortunately, the penstock-bluff is 19 feet 6 inches below the level of the canal-beds. It was calculated by the canal engineers that it would be cheaper to lose this head than to raise the level of the penstock-bluff; therefore, starting at a point about 400 yards from the bluff, a series of three cascades was arranged, each having a fall of 6 feet 6 inches. Just below the cascades the beds of the canals are lined with concrete, and are lowered 4 feet. It is hoped that this extra 4 feet depth of water will act as a cushion for the falling water. The canals terminate in a common masonry intake-basin, means being provided whereby either canal can be dammed from the basin and emptied by sluice-valves. From the intake-basin, which has an overflow-weir and a large sluice-gate for the purposes of flushing, the water flows in three streams through gridiron strainers under sluice-gates into penstock chambers. A small quantity of water also passes through very fine strainers into a settling-tank, and from there through a filter into the governor-reservoir, for the purpose of rendering the water feeding the governor-pistons free from grit.

Penstocks.—The three penstocks consist of riveted steel pipes, each 900 feet in length, graduated between 3 feet 9 inches in diameter at the top of the bluff, and 3 feet in diameter at the lower

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end, and varying in thickness between ¼ inch and ½ inch. To each penstock there are three cast-iron anchorage-pieces, fitted with expansion-joints, and a well-bedded thrust-block at the generating-station. The water from the penstock-tanks passes in each case through a large mushroom-valve into its penstock. On reaching the generating-station it passes through a large throttle-valve, worked by a quadrant with worm-gearing, into a Y-piece, thus feeding two large turbines. A 10-inch cast-iron pipe is also fitted to each penstock, in the generating-station, and from this connections are made for driving the two small turbines for the exciters. A 10-inch pipe descends the bluff from the filter-tank to the generating-station. From this pipe distributing-pipes are taken to the governor piston-valves on all the turbines. The actual head of water from penstock to turbine is 406 feet, but 382 feet 7 inches is the calculated effective head. The penstocks were designed so that any two of the pipes could carry the maximum supply of water required. With this arrangement any pipe could have been shut off for repairs; but with the subsequent arrangement of the machinery this is now found to be impossible without reducing the output of power.

The Generator-Station.—The generator-station is 133 feet in length, 42 feet in width and 26 feet in height to the eaves. It is erected on the bank of the river below the bluff. There are three tail-races immediately below the building, which discharge direct into the river. The building is fitted with a hand-power overhead crane, and with a 5-HP. electrically-driven air-compressor, with receiver, for cleaning the generators by means of the air-blast.

Turbines.—There are in all six large turbines for generators, of which five will work at a time, and two smaller turbines for generator-exciters. They are fixed 7 feet above the highest flood-level. The turbines are of the Pelton-wheel type, fitted on horizontal shafts. The wheels of the large turbines are 4 feet 6 inches in diameter. Each wheel, with its twenty-four double buckets, is made in one piece, of cast steel. The water strikes the buckets of each wheel from two nozzles; the aperture of each, when fully open, is 5 inches by 4 inches. Each of these wheels is designed to give, under normal conditions, 1,015 brake-HP. at 300 revolutions per minute, with a fall of 382 feet 7 inches, and a water-supply of 38 cubic feet per second. The two exciter-turbines are designed to give 110 brake-HP. at 465 revolutions per minute with the same fall, and a water-supply of 3½ cubic feet per second. The guaranteed efficiencies of the turbines are, with full gate, 75 per cent., and at half gate 70 per cent. Each turbine is

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fitted with a governor driven from the shaft, which works a small hydraulic three-way valve. This valve supplies filtered water to two hydraulic pistons, which work, by means of connecting-rods, nozzle throttling valves and a relief-valve. The degree of control required of these governors is considerable; with a gradually-changing load the speed is not to vary more than 1 per cent. from the normal; with a variation of 25 per cent. of full load the speed is not to vary more than 3 per cent.; with a variation of 50 per cent. of full load not more than 5 per cent.; and with a variation equal to full load not more than 10 per cent. Each of the governors is being fitted with a solenoid, so that in cases of necessity they may be thrown out of action from the step-up transformer-station. The turbine shafts are directly connected by flanged couplings to the generators and exciters.

Generators.—There are six alternating-current three-phase generators, made to one standard pattern. Each has ten poles and is designed with mesh winding for a normal full-load output of 720 kilowatts at a speed of 300 revolutions per minute. The normal full-load current is 189 amperes, and the pressure between any two phases is 2,200 volts. Each machine has a stationary armature, which is built of laminated punchings of sheet iron, slotted on the inner side to receive the windings, and furnished with dove-tailed projections on the outer side, by which they are attached to the cast-iron outer frame. Air-ducts are placed at equal distances in the core to allow free circulation of air to the core and windings. The windings are held in place by means of wooden wedges driven into the grooves in the teeth. Any of the windings can be examined and readily replaced, if necessary, by removing a few of the adjacent windings. The field-magnet pole-pieces are mounted on a steel ring, which is carried by a cast-iron spider. In order to obtain greater permeability, and to avoid hysteresis, the pole-pieces are built up of sheet-iron punchings, having one end dove-tailed into the steel ring. The field-coils consist of soft copper strip, wound on edge, so that one edge of the copper is exposed to the air. Each coil is protected by an insulating collar at each end and is well insulated from the iron core. The collector-rings for the exciting current consist of two insulated steel rings mounted on the shaft, and carbon brushes are used. The shaft and bed-plate have been extended so that the armature-frame may be slid parallel to the shaft, leaving both the armature and field-magnets exposed for inspection and repairs. The shaft is made of forged steel, in one piece, and is carried by two large self-oiling spherical bearings, which are supported by

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strong cast-iron pedestals. The insulation between the armature winding and the core has been subject to a test of 5,500 volts alternating current for one minute, and between the field windings and the core to a test of 3,000 volts alternating current for one minute. An efficiency of 96 per cent. at full load is claimed for these machines.

Exciters.—There are two exciting generators, made to one standard pattern. Each consists of a six-pole compound-wound dynamo with a former-wound slotted armature, and is designed for a normal full load of 75 kilowatts at 465 revolutions per minute. The pressure at no load is 110 volts, but this will rise to 115 volts at full load, with an output of 652 amperes.

Generator-Station Switchboards.—A small switchboard panel is provided in the generating-station for each generator. As the generators, in the ordinary course of work, are governed entirely by the switchboard in the transformer-station on the bluff, this switchboard will only be used in cases of emergency.

Masonry Conduit.—All the conductors from the generating-station to the step-up transformer-house consist of lead-covered insulated copper wires. These are carried on stone ledges up the sides of a masonry conduit from one building to the other.

Step-up Transformer-Station.—The main building is 88 feet in length by 32 feet in width, and 30 feet in height from the main floor to the wall-plate. A set-off building, called the "outlet-tower," measuring 25 feet by 10 feet, is provided for lightning arresters, through which the main transmission-wires make their exit. The main building is provided with a hand-power overhead crane and a 5-HP. electrically-driven air-compressor, with receiver, for cleaning the transformers and switches by means of an air-blast. Two electrically-driven blowers (one spare) are provided for cooling the transformers. These are 6 feet 8 inches in diameter by 2 feet 3 inches in width, and are driven by a $7\frac{1}{2}$-HP. induction-motor at 375 revolutions per minute. The main building may be divided into three parts, the basement, 9 feet in height, the main floor, and the high-tension switchboard gallery, 10 feet above the main floor. The conduit containing the conductors from the generating-station enters this building at the basement, and each conductor is carried direct to a point immediately below its individual switchboard on the main floor. Here the conductors from the exciters are taken direct to their respective panels on the main switchboard, and the main generator-conductors, after passing through the instrument-transformers and switches, are connected to the main bus-bars. From the main bus-bars, four

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main circuits are taken through switches and instrument-transformers to their respective main transformers, situated in the main building, entering on the under side. It will be seen that the conductors from the main generators have no direct connection with the main switchboard itself. The main switches are worked from the switchboard by levers and wooden connecting-rods. The secondary or high-tension conductors (30,000 volts) leave the transformers at the top, and are carried overhead on insulators under the gallery, through switches operated by levers and wooden connecting-rods from the high-tension switchboard on the gallery. After passing through the switches the conductors are carried to the bus-bars behind the high-tension switchboard on the gallery. The bus-bars consist of copper wire, well insulated with rubber, and, like all the high-tension conductors, are carried on transmission-pattern insulators. From these bus-bars two circuits are taken for the transmission-wires. On leaving the bus-bars the conductors are carried to oil switches below the gallery, and are then taken direct to the transmission-wires. The transmission-wires, on passing through the outlet-tower, are tapped by conductors leading to the lightning-arresters.

The Step-up Transformer-Station Low-Tension and Exciter Switchboard.—This switchboard consists of fourteen panels of blue marble, 7 feet 6 inches in height by 2 feet in width and 2 inches in thickness, polished on both sides and supported in angle-bar frames. There are six generator-panels, one exciter-panel, four transformer-panels, one output-panel, one station motor-panel and one lighting-panel. There are no fuses, but the rods from the switches to the main switchboard are fitted with automatic trip-catches, which throw out the switches when excess currents pass through. These catches are worked by current from the instrument transformers.

Step-up Transformers.—There are four banks of three single-phase transformers, cooled by air-blast. The transformers are made to one standard pattern, and are of the shell upright type. Each has an output of 400 kilowatts. The transformation is from 2,173 volts to 30,000 volts. The transformers are wound for a frequency of 25 periods per second, and require at full load an air-pressure of $\frac{5}{8}$ ounce per square inch to cool them. The primary coils consist of well-insulated soft copper strip, and the secondary coils of well-insulated soft copper wire. The windings are placed alternately in groups of two or three coils, with thick sheets of ebonite interposed between them. The case is made of cast-iron, with removable sheet-iron panels on each side. The top consists of two panels, each perforated with gridiron slots, so that, by

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sliding the top panel, an egress is provided for the air-blast. The foundations for the transformers are hollowed out to form a channel for the air-blast, which enters the transformers from underneath. The efficiency of each transformer at full load is 98·5 per cent.

High-Tension Switchboard.—There are no measuring instruments on this switchboard, it being used only for the purposes of switching. A set of three switches—one for each phase—is used to connect each bank of transformers to the bus-bars, and a set of three switches is used also to connect each of the two transmission-lines to the bus-bars, making eighteen switches and panels in all. Each switch of each set is mounted in a brickwork stall under its respective panel, and consists of a double-break plug-switch, which breaks its circuit under oil contained in an iron tank. The plug-switch arm is worked by a wooden rod, which in its turn is worked by levers and rods from the panel above. Above each switch-lever panel and between the main switch and the bus-bar is another panel carrying an auxiliary knife-switch, 1 foot 6 inches in length. Between each two of these panels is a marble barrier to prevent an arc passing from one pole to another. This switch will only be used to disconnect the main switches from the bus-bars in the case of repairs being required.

Lightning-Arresters.—On the transmission-wires passing through the outlet-tower, connections are made for the lightning-arresters. These are fixed in six masonry stalls, one stall for each transmission-wire, to prevent all chance of flashing. In each stall twenty ball-and-graphite lightning-arresters are mounted in series, between the line and earth, on wooden scantling, which is carried on transmission-type insulators. Each lightning-arrester consists of a graphite resistance of 10 inches of $\frac{3}{4}$-inch carbon rod and four breaks of $\frac{1}{32}$ inch each, between five brass balls $1\frac{1}{2}$ inch in diameter, mounted on a special porcelain slab. Between the lightning-arresters and the transmission-wires are fixed long-arm knife-switches, so that the arresters may be temporarily cut out for repairs or cleaning.

The Transmission-Line.—The transmission-line is in duplicate, and is carried practically in a straight line between the step-up and step-down transformer-stations, a distance of $91\frac{1}{2}$ miles, the two lines being 60 feet apart. To overcome induction in the lines the wires are transposed about every 10 miles, each transposition consisting of one-third of a turn, so that three complete turns are made in the whole distance. It was proposed, in the original project, to have two change-over stations, situated at about the

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30th mile and the 60th mile of the transmission-wires, so that, in the case of a breakdown on the line, that part of the line could be switched out and the duplicate line would carry a double burden between the two stations where the fault lay, whilst repairs were being made. This plan would have resulted in a loss due to one-third of a line only, in case of a breakdown. The idea was abandoned, however, as these change-over stations would have been costly, both in plant and supervision; and as either line is sufficient to carry the whole current, it has been estimated that it will be cheaper to suffer the loss of the whole of one line for a short time, whilst the repairs, if required, are being carried out. There are forty-four poles to the mile, the poles being spaced 120 feet apart.

To avoid the trouble arising from white ants attacking wooden poles, it was decided to erect composite poles, consisting of an iron base with a wooden top. The iron base is a steel pipe 13 feet in length by $7\frac{5}{8}$ inches in external diameter, and is sunk 6 feet into the ground. The wooden poles are 17 feet in length by 7 inches square, turned for 1 foot 9 inches at the bottom to a driving fit for the steel-pipe sockets, where they are held by $\frac{1}{2}$-inch coach-screws. Thus the composite pole is 28 feet 3 inches in length, and stands, when fixed, 22 feet 3 inches high. The top of the pole is prevented from splitting by a wrought-iron ring, and it also has a galvanized weathering cap. A cross-arm, 4 feet 4 inches in length and $4\frac{1}{4}$ inches by $3\frac{1}{2}$ inches in cross-section, is bolted and braced to the pole with wrought-iron straps, at a distance of 2 feet 11 inches from the top. The insulators on the cross-arm are 3 feet 4 inches apart, the third insulator being fixed on the top of the pole, with the result that all the wires are equidistant from one another. All the poles were made to one standard pattern, and if it happened that a longer pole was required, a standard pole was taken and raised with masonry. Guyed poles, having additional cross-arms to accommodate two insulators per line, were fixed at the summits of inclines and wherever the chief linesman considered them necessary.

The Government of India Telegraph Department have decided to carry their telegraph wires at a minimum height of 8 feet above the transmission-wires. No special precautions are taken in crossing main roads. The height of the lower lines above the ground at the insulators is about 20 feet. It will be seen that, owing to the sag of the wires and to the fact that the roads are generally raised above the surrounding country, the lines will be considerably less than 20 feet above the roads. Difficulty was experienced in obtaining a sufficient number of poles of the size and

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strength required. Ultimately most of them were made from Australian Karri wood, and the remainder were obtained from the great forests of the West Coast of Southern India. The poles are fixed with the cross-arms face to face and back to back alternately. The holes for the poles were dug with special tools; the ground was loosened by a long bar and the earth was scooped out with a modified form of Spanish spoon. No special precautions have been taken to prevent the poles sinking into the ground. In passing over rocky country the holes were prepared by blasting. The insulators are made of the best quality of vitrified porcelain, and have five petticoats. They are $6\frac{3}{4}$ inches in outside diameter, and the height from the bottom to the wire groove is also $6\frac{3}{4}$ inches. The surface distance between the binding wire and the insulator bolt is 1 foot $9\frac{3}{4}$ inches. The insulators were subjected to a test of 60,000 volts before erection. The line consists of half hard-drawn copper wire, 0·32486 inch in diameter, and about 425 tons of wire have been used. The joints are made by passing the ends of the wires through double sleeves and giving the ends four complete turns around the other wire. The entire joint is then well sweated with solder. The wires are bound to the insulators with soft-drawn copper wire. The loss of power in the whole transmission is estimated to be about 12·7 per cent.

Telephone.—The poles of the most northerly transmission-line carry special cross-arms for a telephone line between the two transformer-stations. The telephone cross-arms are fixed 6 feet below the transmission-wire cross-arm. They are provided with glass insulators having two petticoats, and are set 1 foot 6 inches apart. The wires are crossed every fourth pole to neutralize the effect of induction. The headway under the telephone wires is therefore sometimes less than 14 feet.

Step-Down Transformer-Station.—The step-down transformer-station is situated on the Kolar Gold Fields. The building is of the same dimensions, and is supplied with exactly the same instruments, switchboards, etc., as the step-up transformer-station, with the exceptions that, instead of having generator- and exciter-panels, the main switchboard is provided with ten feeder-panels for the ten mines supplied, and instead of having a masonry conduit for the incoming conductors, a distribution-tower is provided, from which the aerial main feeder-lines are taken to the places where power is required. The transformers are of the same type as those in the step-up transformer-station. Each transformer has an output of 350 kilowatts, and the transformation is from 26,182 volts to 2,300 volts.

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Distribution-Tower.—Insulated wires attached to porcelain bobbins are carried direct to the main feeder-wires in the distribution-tower, which is a building 21 feet in length by 18 feet in width, attached to the main building. The main feeder-wires are anchored to strain insulators fitted into strong wooden girders, and pass through special apertures in the walls on three sides of the tower. The insulated wires from the switchboard are soldered to the main wires between the apertures in the walls and the strain insulators. A subsidiary wire, leading to a lightning-arrester in the lower part of the tower, is soldered to each main feeder-line. The lightning-arresters are of a similar type to those used on the high-tension lines, and consist of a graphite resistance of 5 inches of $\frac{3}{4}$-inch carbon rod, and two breaks of $\frac{1}{32}$ inch each between three brass balls 2 inches in diameter; the whole is mounted on a special porcelain slab, the top ball being connected with the graphite resistance, and the bottom ball with earth.

The Main Feeder-lines.—The main feeder-lines are supported on composite poles similar in size and construction to those used on the main transmission-line. The number of cross-arms to each pole varies between one and four. The cross-arms are placed 2 feet apart, and are 9 feet in length by 4 inches in width, and 5 inches in depth. Each cross-arm carries six insulators, 1 foot 6 inches apart, the distance between the insulators nearest the poles being 2 feet. All poles subjected to strains have double cross-arms, and are stayed; at every branch two stayed poles with double cross-arms are fixed at a suitable angle. The clearance under these wires on the public roadways is never less than about 15 feet. The branch feeder-lines are supported on similar poles, but with cross-arms only 3 feet in length, provided with two insulators 2 feet apart, forming, with the third insulator on top of the pole, an equilateral triangle of 2 feet side. The insulators, which are of the best quality of vitrified porcelain, have three petticoats, 5 inches in outside diameter, the height from the bottom to the wire groove being $3\frac{1}{2}$ inches. They are carried by $\frac{5}{8}$-inch steel bolts taper-screwed into maple-wood nipples, which, in turn, are taper-screwed into the insulators. In exceptional cases, such as on curves and terminal insulators, the bolts are 1 inch in diameter, and are fastened to the insulators with cement. The lines are supported on a groove in the insulator about 6 inches above the top side of the cross-arm, and each insulator has been tested at 10,000 volts before erection.

Each mine has its own feeder or feeders from its own panel in the step-down transformer-station. A feeder consists of three

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lines of half hard-drawn copper wire. Four sizes of feeders are in use, namely, Nos. 0, 00, 000, and 0000, B. and S. gauge. The voltage loss in the distribution is about 7 per cent., the average energy loss at full load being 5 per cent. For the Mysore Mine very heavy feeder-lines were required. This has been overcome by running three separate feeders from the same terminals on the panel in the transformer-station. Altogether about 81 tons of bare copper wire have been used for the overhead distribution.

Mine Plant.—The plant for the mines consists of three synchronous motors wound for a pressure of 2,080 volts; eighteen induction-motors wound for a pressure of 2,080 volts; ten smaller induction-motors wound for a pressure of 220 volts, with transformers; thirty-one motor-panels, one for each motor; eleven air-compressors with receivers; five hoists; one pump and all the necessary shafts, couplings, etc., to adapt the existing mining plant for electrical driving.

Work Done.—The following is a list of the motors on the mines, with the work to be done by each.

Mysore Gold Mining Company's property (seven motors):—

Nos. 1 and 2 are 150-HP. induction-motors, which replace two 165-I.HP. steam-engines in driving two 60-head mills having stamps weighing 1,050 lbs., which drop 92 times per minute.

No. 3 is a 100-HP. induction-motor, which replaces an 83-I.HP. steam-engine in driving a 30-head mill having stamps weighing 1,050 lbs., which drop 92 times per minute.

No. 4 is a 10-HP. induction-motor, which replaces a small winding-engine lifting 1 ton of quartz to hopper-level, a height of 27 feet, in 15 seconds.

No. 5 is a 5-HP. induction-motor, which replaces a small winding-engine lifting 1 ton of quartz in a truck to a height of 17 feet, up an incline 70 feet in length, in 30 seconds.

No. 6 is a 300-HP. synchronous motor, which drives a Walker air-compressor, replacing the power derived from the steam-cylinders of the compressor.

No. 7 is a 200-HP. induction-motor, which drives a 200-HP. Ingersoll-Sergeant air-compressor.

Champion Reef Gold Mining Company's property (nine motors):—

Nos. 1 and 2 are 200-HP. induction-motors, which replace two 180-I.HP. steam-engines, driving two 60-head mills having stamps weighing 1,250 lbs., which drop 92 times per minute.

No. 3 is a 15-HP. induction-motor, which replaces a small

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winding-engine, lifting 2 tons to a height of 45 feet up an incline 200 feet in length in 30 seconds.

No. 4 is a 40-HP. induction-motor, which replaces a 40-I.HP. steam-engine, driving stone-breakers and quartz-dressing machinery.

No. 5 is a 150-HP. induction-motor, which replaces a 138-I.HP. steam-engine, driving a 50-head mill having stamps weighing 867 lbs., which drop 92 times per minute.

No. 6 is a 10-HP. induction-motor, which replaces a 10-I.HP. steam-engine driving stone-breakers.

No. 7 is a 15-HP. induction-motor, which replaces a small winding-engine, lifting 2 tons to a height of 35 feet up an incline 120 feet in length in 30 seconds.

Nos. 8 and 9 are two 200-HP. induction-motors, which drive two 200-HP. Ingersoll-Sergeant air-compressors.

Ooregum Gold Mining Company's property (four motors):—

Nos. 1 and 2 are two 200-HP. induction-motors, which replace two 220-I.HP. steam-engines, driving two 60-head mills having stamps weighing 1,250 lbs., which drop 92 times per minute.

No. 3 is a 15-HP. induction-motor, which replaces a small winding-engine, lifting 1 ton to a height of 35 feet up an incline 50 feet in length in 15 seconds.

No. 4 is a 300-HP. synchronous motor, which drives a 300-HP. Ingersoll-Sergeant air-compressor.

Nundydroog Gold Mining Company's property (two motors):—

No. 1 is a 100-HP. induction-motor, which replaces a 110-I.HP. steam-engine, driving a 40-head mill having stamps weighing 900 lbs., which drop 92 times per minute.

No. 2 is a 400-HP. synchronous motor, which drives a 400-HP. Ingersoll-Sergeant air-compressor.

Balaghat Gold Mining Company's property (four motors):—

No. 1 is a 40-HP. induction-motor, which replaces a 41-I.HP. steam-engine driving a 15-head mill having stamps weighing 1,050 lbs., which drop 92 times per minute.

No. 2 is a 30-HP. induction-motor, which replaces a 28-I.HP. steam-engine driving a 10-head mill having stamps weighing 1,050 lbs., which drop 92 times per minute.

No. 3 is a 5-HP. induction-motor, which drives a triplex pump raising 85 gallons per minute to a height of 65 feet through 1,730 feet of 4-inch pipe.

No. 4 is a 200-HP. induction-motor, which drives a 200-HP. Ingersoll-Sergeant air-compressor.

The Oriental, Coromandel, Gold Fields, Nine Reefs and Road

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Block Mines have each one 150-HP. induction-motor driving a 150-HP. Ingersoll-Sergeant air-compressor.

Load.—It will be seen from the foregoing list of work done that the load is one of the steadiest it is possible to obtain for so large a power, the plant working practically at full load day and night. The only unsteady load is the driving of the five hoist-motors and the two motors for the quartz-dressing machinery, which altogether does not amount to 3 per cent. of full load.

Total Efficiency of Plant.—It is estimated that to allow of 4,000 HP. being used at the mines, 5,970 HP. must be delivered by the turbines to the generators. This makes a total allowance of 33 per cent. for losses during transit, or an efficiency of 67 per cent. Taking into account the loss of power at the turbines, the efficiency of which is guaranteed to be at least 75 per cent., the total efficiency of the whole plant is a fraction over 50 per cent.

Agreement.—The following are a few condensed abstracts from the agreement between Messrs. John Taylor and Sons, on behalf of the ten mines under their management, and the Mysore Government.

The contract is to be for 10 years from the date of the first use of the power.

The Government agrees to provide, instal, and, if necessary, house all plant essential for the driving of the existing machinery, and at the end of the first year's operation to hand over the same in full working order, free of charge to the Company using it.

The Government is to supply, with one exception, the electrically-driven air-compressors; and the Companies agree to pay the Government such sum over and above £4 per horse-power as shall have been paid by Government for them. This cost is not to include the electric motor, which is free of charge, in accordance with the previous paragraph.

The Government, whilst taking every precaution to ensure continuity of supply, will not be liable for loss due to any interruption, other than gross negligence on the part of its servants.

The Government shall supply, and the Companies shall take, approximately 4,000 HP. The electrical power of an electric motor is to be taken as equal to the indicator horse-power of the steam-engine it replaces. In the case of new machinery, the power available at the terminals of the motors, in watts, divided by 746, shall represent the horse-power.

The Companies agree to pay the Government the following rates per annum for each horse-power:—

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First year £29; second, third and fourth years £18; fifth year a sum which the Government will determine, not to exceed £24; sixth, seventh, eighth, ninth and tenth years, £10.

These payments are subject to deductions in cases of interruption or diminution in the supply of power.

The power-supply will be discontinued during one predetermined hour in each month, for testing purposes.

The Companies, when they take over the distribution plant at the end of the first year's working, shall use every reasonable means to discover defects and remedy them.

All power for lighting purposes is to be obtained from motor-generators.

The agreement is to be construed according to English law.

In the contract made between the Government of Mysore and the General Electric Company, the Government undertakes to furnish free of cost all buildings, foundations, and foundation bolts for the accommodation of the plant, to carry out all excavations, blasting, masonry and concrete work along the line of the conductors, to furnish all necessary rights of way and permits for the transmission- and telephone-lines, to clear the line to be followed of all trees and jungle-scrub, to provide suitable bridges for the transportation across any streams or gullies of the apparatus and material to be furnished by the contractor, to supply, in order to facilitate the work, sufficient unskilled (*i.e.*, coolie) labour, and to supply all wooden poles and cross-arms for the power- and telephone-lines, in accordance with drawings furnished by the contractor. The contractor, however, is to supply suitable iron sockets 13 feet in length.

The whole undertaking was estimated to cost the Mysore Government the sum of £287,300, or £71·825 per horse-power for 4,000 HP. The distribution having since been increased to 4,185 HP., the actual cost has been £336,267, or £80·35 per HP. The total revenue for the 10 years, according to agreement, will be £657,045. The yearly maintenance costs are estimated to be £11,000, not including depreciation, for which no allowance is being made. Deducting £110,000, the estimated maintenance costs for 10 years, from £657,045, a total return of £547,000 is shown. This is equal to 16·26 per cent. per annum. The mine engineers estimate the cost of steam-power at £30 per horse-power per annum, which gives the total amount expended in 10 years for 4,185 HP. as £1,255,500. If £657,045, the cost of the electrical power for that time, is deducted from this sum, it will be seen that the mines have a surplus of £598,455 in 10 years, together with the whole of the

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distribution plant (as per agreement) less 9 years' upkeep of the plant.

Whether an undertaking of this kind should have been carried out by a Government is perhaps open to question. In the hands of a private Company the scheme would possibly have been a greater financial success, but the Author cannot help applauding the enterprise shown by the Government of this native State.

In conclusion, the Author desires to thank Captain A. Joly de Lotbiniere, R.E., the Deputy Chief Engineer of the Mysore State, and Mr. Axel Ekstrom, the Chief Electrical Engineer for the contractors, the General Electric Company of America, for affording much of the information contained in the foregoing Paper.

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(*Students' Paper No. 489.*[1])

"Notes on the Construction of the Permanent Way of Electric Tramways."

By ROBERT BRUCE, Stud. Inst. C.E.

IN the following Paper the Author presents some notes on the construction of the permanent-way of electric tramways, which it is hoped may be of interest to municipal engineers and others, a really first-class permanent-way being essential to the successful management and operation of an electric tramway system.

Rails.—In designing a rail, too much attention cannot be paid to the various considerations which must necessarily be of importance in deciding the life of the rail. The rail must not be so brittle as to break when bent to an arc of small radius, nor must it be so soft as to be readily worn away by the car-wheels. What is required is a rail as hard as possible to resist wear, but so tough as not to break easily, and still sufficiently ductile to allow of its being bent to the required radius. Rails should be made of the best quality of Bessemer steel, having a chemical composition in conformity with the following specification:—

Carbon	between	0·45	per cent. and	0·60 per cent.
Manganese	„	0·80	„ „	0·95 „ „
Sulphur	not to exceed			0·06 „ „
Phosphorus	„		„	0·08 „ „
Silicon	„		„	0·06 „ „

A piece of rail, 5 feet in length, placed directly on solid iron bearings, 3 feet apart in the clear, with its head uppermost, should be capable of resisting a blow on its centre from a weight of 1 ton falling freely from a height of 9 feet, without deflecting more than 1 inch, and, after having been so tested, should be capable of sustaining, in the same position, a second blow on its centre from the same weight falling freely from a height of

[1] Paper read before a meeting of the Manchester Association of Students of the Institution on 26 March, 1902.

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22 feet 6 inches, without exhibiting any sign of fracture. Strips cut from the rails should have an ultimate tensile strength of 37 tons to 45 tons per square inch of original section, with an elongation at rupture of at least 15 per cent. in a length of 8 inches. The section of rail should be such as to give great stiffness, but with as small an area as possible exposed on the surface of the street. The width of the rail at the head should not exceed $3\frac{3}{4}$ inches. The flange or base of the rail should be of sufficient width to distribute the pressure over the underlying concrete bed, and also to prevent any side-tilting of the rail. It has been found by experience that a base of $6\frac{1}{2}$ inches or 7 inches in width serves the purpose very well. The depth of the rail will be governed, to a certain extent, by the depth of the paving-setts to be used, but a depth of 6 inches to 7 inches will be found to be convenient. The web of the rail, which may vary between $\frac{3}{8}$ inch and $\frac{1}{2}$ inch in thickness, should be so placed as to be as nearly as possible directly below the point of application of the load, thus minimizing the side-tilting tendency already referred to.

Within the last few years there has been a growing tendency on the part of engineers to widen, and also to increase the depth of, the groove of the rail. The deeper and the wider the groove is made, however, the greater is the danger to cyclists and to light vehicular traffic, and the trouble in cleaning out the grooves. Grooves are now rolled as much as $1\frac{1}{8}$ inch in depth and width, which may be increased to $1\frac{1}{4}$ inch on sharp curves. The lip of the rail is usually rolled $\frac{1}{8}$ inch to $\frac{3}{16}$ inch lower than the tread of the rail, and is about $\frac{1}{2}$ inch in thickness, but it has been found advisable to roll this slightly higher and thicker for sharp curves. A width of $1\frac{3}{4}$ inch is sufficient for the tread, which may be either flat or very slightly convex on the top. All rails should be drilled at each end with holes for fish-plates, sole-plates and bonds, and should be slotted for tie-bars at the required intervals. Fish-bolt holes are usually $\frac{1}{8}$ inch to $\frac{1}{4}$ inch larger in diameter than the bolt, and bond-holes should be $\frac{1}{16}$ inch smaller in diameter than the terminal of the bond. Slot-holes for tie-bars may be punched. The Author does not see the necessity for making the fish-bolt holes in the rail larger than is required to let the bolts pass through easily, as expansion and contraction of the rails in this country is practically nil. Especially is this the case where "anchor-plates" have been used, these being riveted to the flanges of the rails at each joint, and thus preventing any longitudinal movement. The weight of rail per yard varies according to the section, and a weight of 93 lbs. to 100 lbs. per yard is sufficient for

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all requirements; some engineers, however, have adopted a rail weighing as much as 108½ lbs. per yard. In *Fig. 1* is shown the section of a rail and fish-plates, the dotted lip representing the increased thickness for rails on curves. The rail weighs 95 lbs. per yard, and the fish-plates weigh 52 lbs. per pair.

There has been much discussion recently amongst engineers as to the most convenient length of rail. Formerly, rails were rolled up to only 36 feet in length, but at the present time 45-foot and 60-foot lengths are quite common, and it is possible to have rails rolled in 90-foot lengths. The majority of engineers prefer the 45-foot lengths, the chief objection to the longer rails being that they are awkward to handle. Having had experience of both 45-foot and 60-foot lengths, the Author is of opinion that the

Fig. 1.

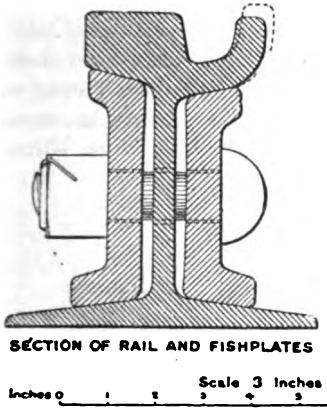
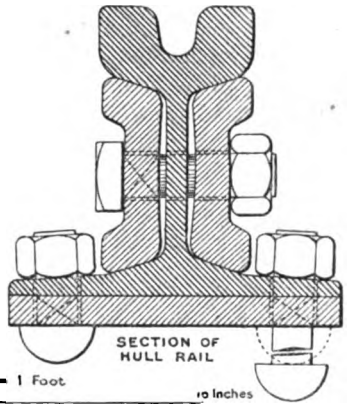
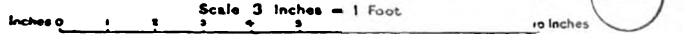


Fig. 2.





latter are to be preferred for the following reasons:—With the 60-foot rails, the number of joints required being less for a given length of track than with the 45-foot rails, a saving is effected in fish-plates, sole-plates, bolts and nuts, and bonds, and in time and labour required for fixing all these; there being also fewer joints, there is less risk of loss of electric current, and, the track being more continuous, easier running for the cars is ensured. The track can also be laid more expeditiously, and, with the proper appliances, such as rail-carriages, barnacles, etc., the 60-foot lengths can be moved about as easily and as quickly as the 45-foot lengths.

A somewhat novel departure has been made by the Hull Corporation, who have laid down a very extensive tramway system with a centre-grooved girder-rail (*Figs. 2* and *3*) having a tread on each side of the groove, and their mode of construction is being rigidly

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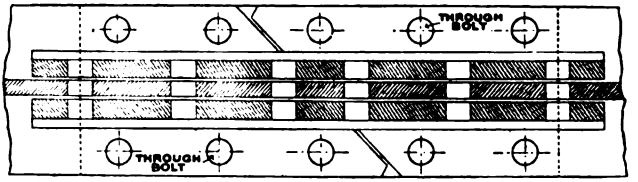
followed by the Doncaster Corporation. A new form of rail, which has been extensively used on the Continent, is the Demerbe rail, a section of which, with fish-plate, is shown in *Fig. 4.* The tie-bars for this rail have neither screws, bolts nor nuts, which might work themselves loose, but are secured by wedges. This

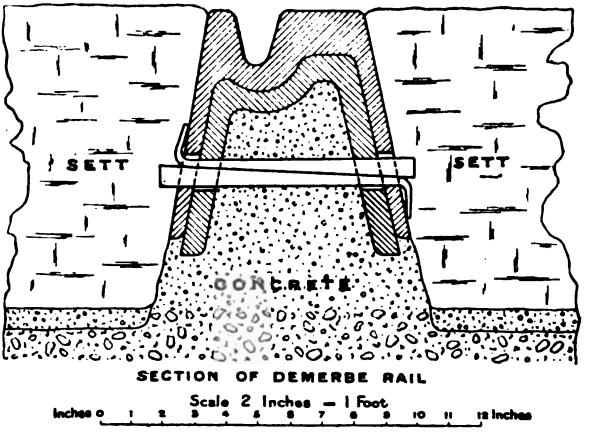
Fig. 3.



PLAN OF RAIL-JOINT; HULL TRAMWAYS.

rail has been adopted at Bradford, and is at present being laid by the Bolton Corporation. It makes an excellent track, it is cheaper in first cost of construction than the girder-rail, and once constructed the cost of maintenance is almost *nil.* A very interesting piece of tramway-work has recently been executed at Fitzalan

Fig. 4.



Square, Sheffield, where three double tracks cross, *Fig. 5.* This junction is subjected to an exceptionally severe service of cars, is situated on a steep gradient, and has a cross-fall in the wrong direction. When originally laid with the ordinary steel rails, points, and crossings, the permanent-way was constantly under repair, owing to the rapid wearing of the different parts. It was

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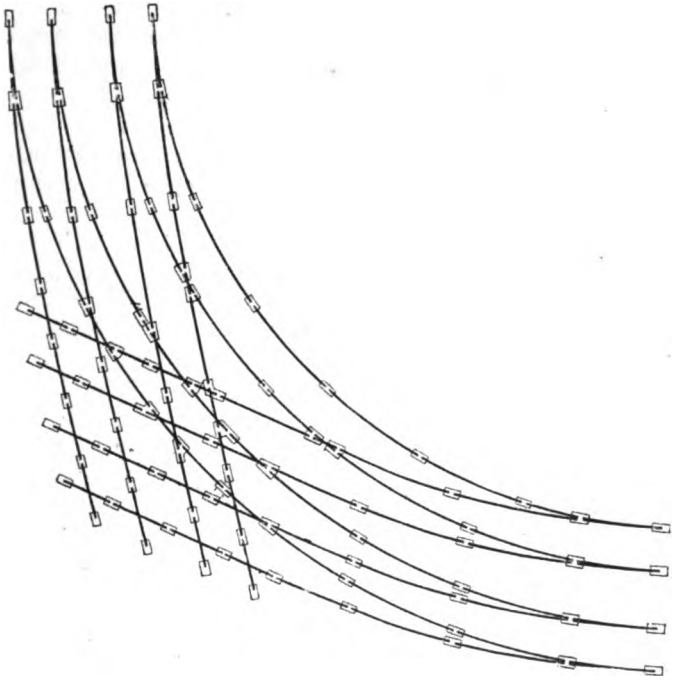
then decided to re-lay the junction with rails, points, and crossings made of manganese-steel, the invention of Mr. R. A. Hadfield, M. Inst. C.E. This special steel is so hard that it is practically impossible to machine it, and at the same time it is so tough that when cold it can be bent and twisted without breaking. The rails are of bridge-section, and were cast in lengths of about 13 feet, cross-ribs being cast at intervals of about 1 foot 6 inches, to give greater strength and rigidity. The rails were bolted down to

Fig. 5.



PLAN OF SPECIAL TRACK-WORK AT FITZALAN SQUARE, SHEFFIELD.

cast-steel sole-plates, and a half-hole was cast in the end of each rail near the top, through which, when the rails were fixed in position, a bolt was driven, which prevents any vertical motion of the rails relative to each other, and which also prevents any lateral movement after the nut has been screwed on. The whole of the work was constructed by Messrs. Hadfield's Steel Foundry Company, Limited, Sheffield, and up to the present time has given every satisfaction.

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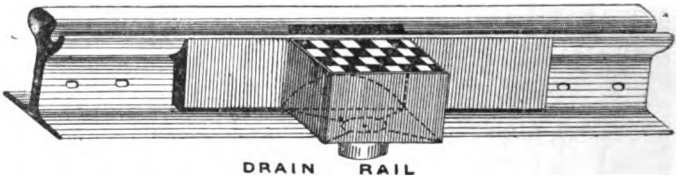
The question of a standard rail for this country is at present being considered by the principal Societies interested. The advantages of such a rail would be enormous. With a standard rail, it would necessarily follow that fish-plates, joint-plates, bolts and nuts, platelaying tools, and in fact everything appertaining to rails and rail-laying, would be made from standard patterns. This would be an advantage alike to manufacturers and buyers, as rails and their appurtenances could then be kept in stock, and could therefore be supplied at less cost and with greater despatch than at present. Then, if a tramway route had to be extended after the lapse of a few years, or if it were desired to connect the tramway systems of two towns, the same section of rail could be procured without any difficulty, which would obviate the necessity of having two or more sections of rail on one route.

Drain Rails.—It will be readily understood that, where hollows occur in a road, the water running down the grooves of the rails in wet weather will of necessity collect in these places and cause

Fig. 6.



a nuisance. To carry away this water, drain-rails of cast steel (*Fig. 6*), having a slot 9 inches in length in the lip of the rail, are often put in and connected to the public sewer, but there are many objections to these rails. Their short length, about 5 feet 6 inches, necessitates the making of joints very close to each other, which is not desirable, and they cannot be laid on sharp curves. An improved method is to drill a slot through the lip of the rail, 8 inches to 10 inches in length, and at this point to fix a drain-box (*Fig. 7*) to the rail, by two bolts passing through the web, the box being then connected to the public sewer. These boxes are 14 inches in length by 6 inches in width, the depth being determined by the depth of the rail.

Rail-Joints.—The provision of a good rail-joint is of the first importance, as it is the life of the joint which determines the life of the track, and it will be found advantageous to easy running, and also economical, to have the joints made as strong as possible. It has been found from experience, that, owing to the comparatively

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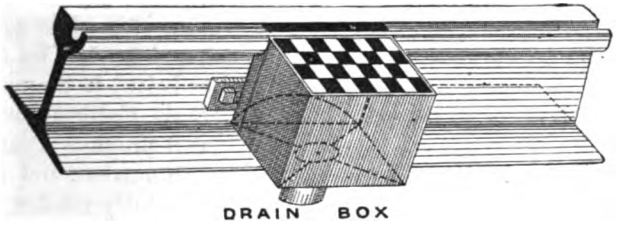
small range of temperature which obtains in this country, and the fact that a very small area of the rails is exposed to these changes, the elongation and contraction of rails due to change of temperature is so small that it may be entirely disregarded, and that consequently the joints of the rails should be as close as possible. This has been accomplished most successfully in the welded joints, which will be referred to later. Formerly, in this country, fish-plates only were used at the joints, but since the introduction of electric traction, which has brought with it increased loads and greater frequency of running, it has been found necessary to increase the weight of the rails and also to strengthen the joints. Fish-plates should be rolled, and should be made of the best quality of mild steel, with 0·20 per cent. to 0·30 per cent. of carbon, one fish-plate being punched with the required number of square holes, and the corresponding fish-plate having the same number of drilled holes. The holes are usually made $\frac{1}{16}$ inch larger than the dia

Fig. 7.



meter of the fish-bolt. Test-pieces cut from the fish-plates should show a tensile strength of 27 tons to 32 tons per square inch of original section, with a minimum elongation at rupture of 20 per cent. in a length of 8 inches. The fish-plates should not be less than 1 foot 8 inches in length, and are usually secured by four or six 1-inch bolts and nuts. To strengthen the fish-plate joint, many devices have been introduced, of some of which the following are brief descriptions:—

"Marshall" joint-plates (*Fig. 8*) consist of ordinary flat sole-plates, about $\frac{1}{2}$ inch in thickness, with either tapered strips, tapered washers or clips, on the top side of the rail flanges, securely bolted to them through the flanges of the rails.

"Angle" fish-plates consist of ordinary fish-plates having projecting pieces which are bolted to the flanges of the rails. The joint is further strengthened by the application of a "twin-bolt" exactly at the place where the two rails meet, which it will be readily understood is the most vital part of the joint. The twin-

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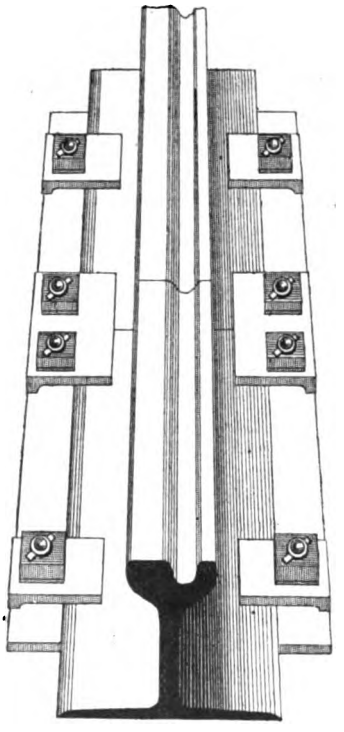
bolt also prevents the percolation of water to the underside of the rail. An example of this arrangement, called the "Victor" joint, is shown in *Figs. 9*.

The "Dicker" joint (*Fig. 10*), which has been used by many engineers in this country, has an ordinary fish-plate on the grooved side of the rail, whilst on the other side the tread of the rail is cut away, and the fish-plate is continued up to the level of the upper surface of the rail, and the load then runs on the upper surface of the fish-plate over the joint. This joint, however, is not suitable for use at points and crossings.

Fig. 8.



MARSHALL. JOINT-PLATES

Another joint which is being extensively used at the present time is the "Anchor" joint, *Fig. 11*. This joint may be made with or without fish-plates, and consists of a piece of rail, inverted, and having its flange riveted or bolted to those of the rails. It is claimed for this joint that it provides a path for the electric current, and it has been successfully used without bonds.

A somewhat novel joint, used at Portsmouth, which is a combination of the "Continuous-Rail" joint and the "Dicker" joint, is illustrated in *Figs. 9*.

The "Rail Shoe" joint (*Figs. 12*), which is of recent introduction, consists of three parts, viz., a large curved bar A, a small curved bar B, and a wedge C. The bars are made of cast steel and the wedge of Martin steel, and are fixed in the following manner:—After the rail ends have been cleaned, the small bar B is fixed on the flange of the rails on one side, the large bar A is then placed on red-hot from the opposite side, and firmly pressed with a specially-constructed lever, and the wedge C is then firmly driven in. These joints may be made with or without fish-plates. Besides being strong mechanically, it also forms a good electrical contact

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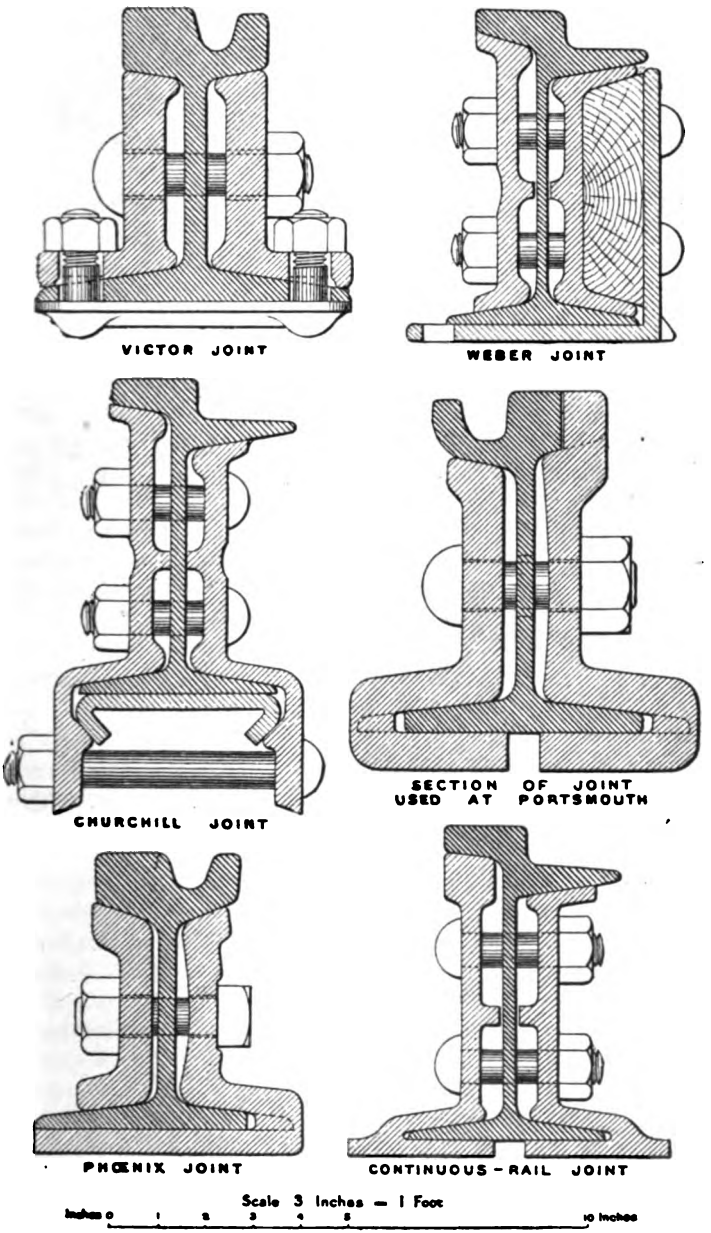
Figs. 9.



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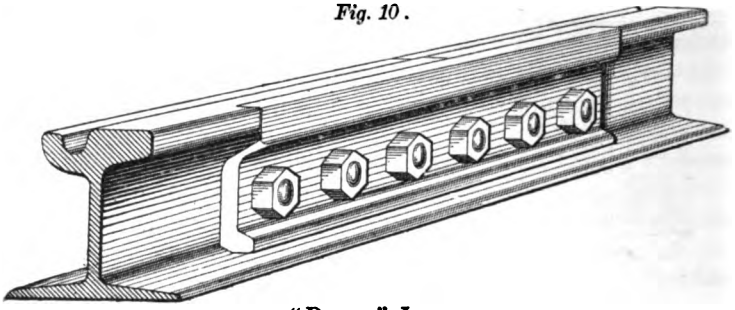
for the return current. The cost of this form of joint is only half that of the cast-weld joint. It has been extensively used in Austria-Hungary.

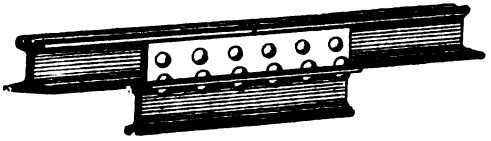
Fig. 10.



"DICKER" JOINT.

The "Phœnix" joint (*Figs. 9*) consists of a combination fish-plate and sole-plate on one side of the joint, the fish-plate being bent

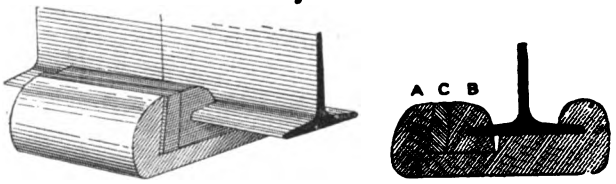
Fig. 11.



"ANCHOR" JOINT.

round the flange, which is partly cut away, and butting on the bottom of the rail for the whole width of the flange, with an ordinary fish-plate on the other side.

Figs. 12.



RAIL SHOE JOINT

The "Weber," the "Churchill," and the "Continuous-Rail" joints (*Figs. 9*) are all types of joints which have been extensively used in America. They are heavier than the joints used in this

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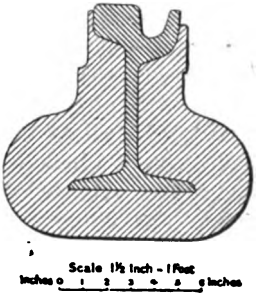
country, all of them having some form of sole-plate. In the "Weber" joint a piece of wood is used, as shown in *Figs. 9.*

In the "Demerbe" rail (*Fig. 4*), only one fish-plate is used at the joint; it is situated below the rail, and exactly fits its under side. This fish-plate is kept in position by means of cotters or wedges driven in from each side of the rail.

In the Hull tramways (*Figs. 2* and *3*) the ends of the rails are cut off at an angle of 45°, and are secured by fish-plates and sole-plates, with the further addition of holding-down bolts with square washers, which extend to the underside of the concrete.

Welded Joints.—There are three different kinds of welded joints, viz., "cast-weld," "electric-weld," and the "Goldschmidt" or "aluminium-weld." The "Falk" cast-weld joint (*Fig. 13*) is formed by making a casting of iron of special chemical composition round the rail ends. These are first cleaned with an emery wheel, or with the sand-blast, and are then encased in iron moulds, into which the molten metal is poured. This molten metal cooling rapidly on the outside surface, an enormous pressure is exerted on the liquid metal in contact with the rail, and it is forced into the interstices of the steel. When the metal has cooled the moulds are removed. These joints have been used at Coventry and Norwich. A new system of cast-welding, very similar to the "Falk" joint, and less expensive, has been introduced by Mr. W. Austin, of Milwaukee, U.S.A., and has been largely used in that town with satisfactory results. In making the electric-weld joint, the rail ends are cleaned as before, and small pieces of steel are applied to the rails on each side. A strong current of electricity is then passed through these, raising the pieces of steel and the parts of the rails in contact with them to a welding heat. Pressure is then applied until the whole becomes one mass. In the Goldschmidt weld joint the rail ends, after being cleaned, are encased in sheet-iron moulds, and are then raised to a welding heat by pouring into the moulds a mixture of molten iron and aluminium. The rail ends are then firmly pressed together by means of specially-constructed clamps, which are fixed on the joint. When the moulds are removed, the solid mass on each side of the rail is knocked off. In this joint one of the rails has always to be free to allow of the end pressure being applied, and this constitutes a serious objection

Fig. 13



"FALK" CAST-WELD JOINT.

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when the joint is to be applied to an existing tramway, as the whole of the existing paving would have to be lifted. With welded joints no bonds are required, but so far neither the electric-weld joint nor the Goldschmidt weld joint has been used in this country, the principal objection to the welded joints being their cost.

Tie-Bars, Bolts and Nuts.—Tie-bars should be made of the best quality of mild flat-bar steel, capable of showing a tensile strength of 24 tons to 28 tons per square inch of original section, with a minimum elongation of 25 per cent. in a length of 8 inches. They should not be so thick as to require a wide joint between the paving-setts, and are usually 2 inches by $\frac{3}{8}$ inch in cross-section, having one end notched for fitting through the web of the rail, and the other end forged to a $\frac{3}{4}$-inch round bar, screwed for a distance of $4\frac{1}{4}$ inches, and provided with two nuts and washers. It is also advisable to have some of the tie-bars screwed at both ends, as these can then be cut into two shorter tie-bars for use at passing-places and junctions, and in special track-work. A convenient distance for spacing tie-bars is 7 feet 6 inches apart, and with 60-foot and 45-foot rails this allows them to be 3 feet 9 inches on each side of the joints. Bolts and nuts should be of the same quality of steel as the tie-bars, the bolts for fish-plates (*Fig. 1*) being usually 1 inch in diameter, with round heads, square shoulders and square nuts, and the nuts should be of an approved lock-nut type. For fixing joint-plates and sole-plates $\frac{3}{4}$-inch bolts are usually used, with round or square heads, square shoulders, and square or hexagonal nuts. Hexagonal nuts are more easily screwed tight in a confined space than square nuts, unless a box-spanner is used.

Points.—At the present time, points are usually made of crucible cast-steel, or of manganese-steel; in some cases only the tongue of the point is made of this special steel. Manganese-steel has been largely adopted in the United States both for points and crossings; its cost is slightly higher than that of crucible steel. Chilled-iron points, although very durable, are not made of sufficient strength to resist the heavy pounding of the electric cars, as the section required would have too large an area of metal exposed on the surface of the street. Points are called either "right" or "left" hand, according to whether they lie on the right or left hand, when seen in the road, looking from the "toe" to the "heel," and they may be either straight or curved on either or both grooves. Points for ordinary track-work vary in length between 7 feet 6 inches and 10 feet, whilst for special track-work, as in a car-depôt, they are usually made

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shorter, being sometimes only 5 feet 6 inches in length. A suitable length for straight points is 7 feet 6 inches; the length of curved points is determined by the radius of the curve. For straight-run-in passing-places, points curved on one groove are very suitable, but the radius should not be less than 125 feet. For special car-depôt work, where the curves are usually of small radius, the points should be curved, and the track should be so designed as to have as many of the points as possible to one pattern. With curved points the "toe" end of the tongue is liable to be rather thin and unable to resist the lateral pressure of the car-wheels without being damaged, but this difficulty can be overcome by increasing the thickness of the base of the tongue. Special "three-way" or "three-throw" points are sometimes made, which, as the name implies, allow the cars to go in either of three directions from a certain point. They are not often used, however, engineers preferring to lay one pair of points slightly in advance of another pair. Automatic points are now made which can be changed to movable points, or *vice versâ*, in a few minutes, without disturbing the paving, and the tongues have as large a bearing-surface at the "toe" end as at the "ball" end, and can be quickly taken out if required. Movable and automatic points are usually laid with open points for mates, but occasionally they are laid in pairs, the tongues being connected by a steel rod. This method has the advantage of ensuring a continuous bearing-surface for the wheel-tires, which is not obtained with the open point. It will be found advantageous to have the points for a car-depôt made with lever-attachments, as they can then be more easily manipulated. In open points, and also in crossings, the depth of the groove is usually reduced in the centre, the bottom of the groove being sloped from the centre to each end of the casting, so that the wheels, when passing over, run on their flanges. The core-hollows of the points and crossings should be filled with concrete before these are laid.

Crossings.—Various forms of built-up crossings are used, some consisting of rails cut and spliced together, or of rails and cast-pieces joined together, but these require special fish-plates and are not to be recommended, as they generally wear quickly and very often work loose. Crossings, which should not be at a smaller angle than 1 in 9, are usually made of crucible steel or of manganese steel, whilst in American practice special hardened renewable-pieces are provided where the greatest wear occurs, both in points and in crossings. For straight passing-places a standard angle of crossing may be adopted, crossings of 1 in 5½ with 30 feet of lead,

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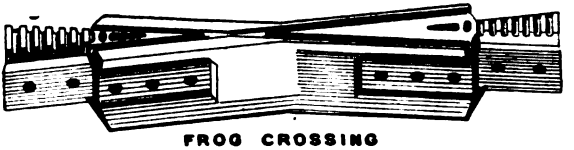
or 1 in 6 with 32 feet of lead, being suitable for town traffic. Crossings should not be longer than is necessary to allow of a sufficient width at the ends for the rails to be joined up to them. The usual form of crossing is the "frog" shape (*Fig. 14*) which has projecting pieces or "frogs" at the ends, to which the rails are bolted. The Hadfield and Hatton "sole-plate" crossing (*Fig. 15*) has a very small area exposed on the surface of the street,

Fig. 14.

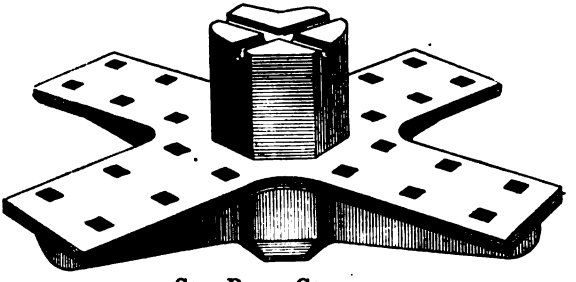


FROG CROSSING

and the rails are bolted to the sole-plate of the crossing. No fish-plates are used with this crossing, and it is cheaper than the "frog" crossing. Where two or more crossings occur close together, or where a point is close to a crossing, a special casting should be made in one piece.

Heel-Plates.—Heel-plates or filling-in pieces are used at the "heels" of points, and at the ends of crossings (if required) to fill

Fig. 15.



SOLE-PLATE CROSSING.

up the narrow space between the rails, until a sufficient width is obtainable for paving. Heel-plates are usually made of cast steel, and, to prevent their lifting, should be formed to fit the sides of the rails, and should be chequered on the upper surface to provide a better foothold for horses. They should not be less than 3 inches in width at the wider end, and are sometimes additionally secured by the last fish-bolt of the joint passing

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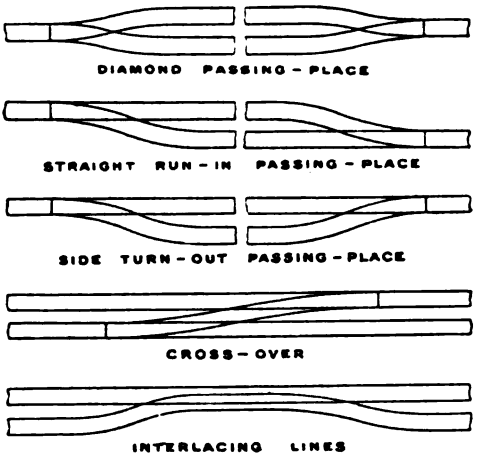
through them. Hardwood blocks, cut to the required size and bedded in cement, make a very good substitute for heel-plates.

Passing-places, Cross-overs, etc.—In a single line of tramway, passing-places of not less than 3 chains in length should be laid at intervals to suit the service of cars to be maintained, but in no case should the distance between them exceed ¼ mile. When the route takes a winding course these passing-places should be situated at such intervals that it is possible for the driver of a car at one passing-place to see a car at the next passing-place. Passing-places are usually made to one of three forms, or to modifications of these forms, *Figs. 16*. For straight track the equilateral or diamond shape is most suitable, the angles of diver-

Figs. 16.



gence from the centre-line at the points being equal; and being symmetrical it interferes least with the road traffic. The straight-run-in passing-place necessitates the gradual divergence of the track from the centre, for a distance of 60 feet to 80 feet from the toe of the points, and although having a straight run-in it has the whole of the angle of divergence on one side of the centre-line at the run-out. The side turn-out, or lateral passing-place, is not to be recommended, as it has the whole of the angle of divergence on one side of the centre-line at both ends. In a double line of tramway, cross-overs about 80 feet in length (*Figs. 16*) should be laid at distances apart not exceeding ½ mile. The distance between the tracks varies according to the dimensions

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of the cars, but tracks of 4 feet 8½ inches gauge are usually laid 8 feet apart, centre to centre, which gives about 3 feet of clearway, according to the width of the tread of the rail. Interlacing lines of tramway (*Figs. 16*) although they effect a saving in points, constitute a very great source of danger to the car-traffic. For the reconstruction of tramways, temporary cross-overs, which can be laid in a short time, are very useful, as by this means the car service can be maintained while the work is in progress. For passing-places situated on curves, and for all double junctions and special track-work, such as spiral easement- or transition-curves, large-scale drawings should be prepared, from which the angles of the crossings and the radii of the curves can be determined, and also the lengths of leads required. All this special work should be first laid out and fitted together in a shed, or on a level piece of ground, before being laid in the street, and the greatest care should be exercised in the setting-out, as a slight variation may make a great difference in the smooth running of the cars, and also in the appearance of the work when finished.

Excavation.—The carriage-way within the tramway limits is usually excavated, to a depth of 6 inches to 6½ inches more than the depth of the rail, below the intended finished level of the road. In macadamized roads, or in roads which have been paved on the top of macadam, a depth of 12 inches or more of metal or pitching will sometimes be found, which has become thoroughly consolidated by the traffic. In such cases it is only necessary to excavate a sufficient depth for the rails, as the remaining metal serves for a foundation quite as well as concrete. If, at any place, the bottom of the excavation is not firm and solid, the excavation is carried to such a depth as may be required, and is then filled in with broken stone or concrete. The bottom of the excavation is well rammed and beaten, and is then swept and watered through a rose, before the concrete is put in.

Concrete Foundations.—The whole of the permanent-way is given a foundation of Portland-cement concrete, not less than 6 inches in depth, except in the case already mentioned, and extending for a distance of 1 foot 6 inches beyond the heads of the outside rails. The concrete is composed of 1 of Portland cement, 2 of clean rough sand, and 4 of clean, hard, solid stones broken to a uniform size to pass through a 2-inch ring, and screened free from dust through a ½-inch riddle. Various methods of laying this foundation are employed, the following two methods being those most generally adopted :—In the first method the rails are laid in the hole, true to line and level, and are supported on concrete-blocks, wood-blocks, or

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old paving-setts, about 15 feet apart. The concrete is then put into the hole and is packed below the rail-flanges by means of shovels or "punners." This method is open to the objection that the concrete, when hard, may not support the rail continuously, but only at intervals here and there, and possibly only at the original supports. The Author has seen a rail taken up which was laid in the manner described, and has found here and there spaces of quite ½ inch between the upper surface of the concrete and the bottom of the rail-flange. The second method, which the Author considers to be much better, is to put in a 5-inch layer of concrete, so that its upper surface will be as nearly as possible 1 inch below the finished level of the flange. When this has set, the rails are laid true to line and level, and are supported at intervals of about 10 feet on hardwood slips of the required thicknesses. The space between the flange and the concrete is then thoroughly packed with beaters from both sides of the rail simultaneously. This packing is composed of the best Portland cement and clean sharp sand gauged 1 and 2, or of cement, ½-inch granite, or other hardstone chippings and sand, gauged 1, 1, and 2, and is only slightly damped before using. A layer of concrete, 1 inch to 1½ inch in thickness, but composed of a finer aggregate than the bottom layer, is then spread over the surface, which has first been well brushed to remove dust, and watered through a rose. The upper surface of this concrete, when finished, is slightly above the flange of the rail, and thus prevents the passage of water to the underside of the rail. It is not necessary to make the upper surface of the concrete smooth, as, if left rather rough, it forms a bond with the bedding for the setts. When wood-paving is to be laid, the upper layer of concrete is composed of 1 of Portland cement, 3 of ½-inch granite or other hardstone chippings, and 1 of sand, and is floated, the surface being made perfectly smooth and to the required convexity. In some places, notably in Hull and in Doncaster, the rails have been laid on longitudinal redwood sleepers, 4 inches in depth by 7 inches in width, which are themselves laid on a concrete foundation 6 inches in depth.

Platelaying.—This constitutes one of the most important features of the work. If the rails have been roughly handled in loading and unloading, they will be found to be more or less "crippled," and will require to be straightened. This is generally done by means of hydraulic "crows," *Fig. 17*. These are also used for bending rails for sharp curves, or where a sudden change in the gradient of the road occurs which necessitates either a concave or a convex curve in the surface of the road. The power for the hydraulic crow is

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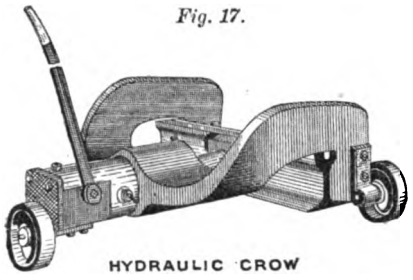
supplied either by water or glycerine, or a mixture of these, and it is easily worked by one man with a lever 27 inches in length. Each hydraulic crow should be supplied with bosses to fit the top and bottom and each side of the rail. Any small irregularities which are observed on the running surface of the rail after it has been laid in position may be eliminated by means of a small crow applied to the head of the rail. When using this crow a small brass filling-piece about 3 inches in length, and shaped to fit the groove of the rails, is placed in the groove at the point where the pressure is applied. On curves of less than 70 feet radius, the crow is applied at points not exceeding 12 inches apart, and wooden templates are made for all curves less than 100 feet radius. In a single line of tramway, where the road is fairly level and straight, the rails are laid to the same level. For a double line of tramway, under the same conditions, the two inside rails are laid to the same level, whilst the two outside rails are laid $\frac{3}{4}$ inch below that level, but if the double line be laid on a gradient the outside rail of the down-grade track should be laid at least level with the inside rails, whilst the up-grade track may have $\frac{1}{2}$ inch of cross-fall. Where rails are laid on curves, super-elevation of the outer rail is essential to safe running. Opinions differ as to the amount of super-elevation required, but the Author has found the following to be suitable, in practice, for a track of 4 feet $8\frac{1}{2}$ inches gauge:—

Fig. 17.



HYDRAULIC CROW

Radius of Inner Rail.	Super-Elevation of Outer Rail.	Radius of Inner Rail.	Super-Elevation of Outer Rail.
Feet.	Inches.	Feet.	Inch.
30	3	60	$1\frac{1}{2}$
35	$2\frac{3}{4}$	65	$1\frac{1}{4}$
40	$2\frac{1}{2}$	70	1
45	$2\frac{1}{4}$	80	$\frac{7}{8}$
50	2	90	$\frac{3}{4}$
55	$1\frac{3}{4}$	100	$\frac{5}{8}$

When curves occur on a down-gradient, the super-elevation should be increased by $\frac{3}{8}$ inch to $\frac{3}{4}$ inch according to the steepness of the

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gradient. Unfortunately, a fixed rule for super-elevation of rails cannot be always strictly adhered to, as the formation of the road, in many instances, does not lend itself to the lie of the rails. Curves of less than 40 feet radius should not be laid in street-track, and none less than 30 feet radius should be laid in car-depôt track. Besides the grooves of the rails being slightly widened on sharp curves, the gauge should also be kept rather wide, and when a double line of tramway is laid on a sharp curve the clearway between the tracks must be widened to the required distance, to prevent the overhanging ends of the cars from fouling when passing on the curve. The joints of the rails should be laid square with each other, and the contact surfaces, where fish-plates, joint-plates, sole-plates, etc., are fixed, should be cleaned before these are screwed tight, to remove any dirt or other foreign matter which might cause a bad fit between any of the parts. Rails should always be cut with a rail-saw, and not with sates, as this always leaves a rough edge on the end of the rail. To allow of the gradual merging together of the rails at points and crossings, a piece of the flange on one side of the rails has to be cut off; this may be done with sates. The greatest care must be exercised in laying rails, points, and crossings to the exact gauge, as, unless this is done, the constant grinding of the car-wheels very rapidly wears away both the rails and the wheel-flanges.

Bonding.—To conduct the return electric current from rail to rail, bonds of various kinds have been introduced. Two bonds are usually fixed at each joint, but in some cases three bonds are provided, and in addition to these, cross-bonds are fixed at intervals, connecting the two rails in a single line, or all four rails in a double line of track. The spacing of these cross-bonds varies considerably in different towns, the distances ranging between 40 feet and 200 feet, but 120 feet is the most usual distance. This distance should be doubled for cross-bonds connecting the tracks in double line. At Norwich, cross-bonds are fixed 200 yards apart, and at Birmingham they are ½ mile apart, while at Carlisle they have been dispensed with altogether. Where points and crossings occur, the rails may either be bonded direct to the castings, or the bonds may pass from rail to rail on each side of the castings, or both methods may be adopted simultaneously. The best-known types of bonds are the Edison-Brown plastic bond, the Chicago bond, the Neptune bond, the Chicago Crown bond, the Columbia bond, and the Glover horse-shoe flexible bond. For the Edison-Brown bond (*Figs. 18*) no holes are required in the rail, the bonds being held in position and protected by the fish-plates. It consists of an elastic

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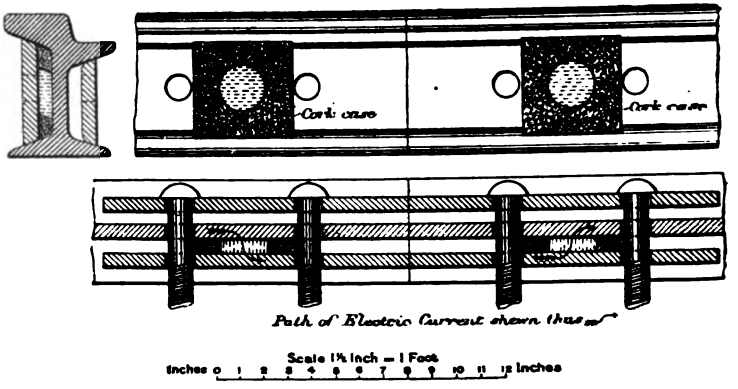
cork case surrounding a plastic metal compound. When the bonds are to be applied, small disks of about 2 inches in diameter, on the web of each rail and on corresponding parts of the fish-plate, are cleaned and rubbed over with a special alloy, which instantly changes any iron-rust to pure metallic iron, forming a bright deposit which will not corrode. The cases are then placed over the prepared surface of each rail, plugs of the plastic compound, each surrounded with a steel spring-washer, are placed in the holes, and the fish-plates are then tightly screwed up, compressing the cork to half its original thickness, and holding the bonds firmly to the rails. Even should the bolts loosen, and the fish-plates become slack to the extent of $\frac{1}{4}$ inch, the bonds will expand, owing to the adhesion of the compound and the cork to the steel, and so main-

Figs. 18.



EDISON-BROWN RAIL-BOND.

tain electrical contact. The Chicago bond consists of a solid rolled round copper rod, having thimble-shaped terminals which are bent at right angles to the bond. These terminals are inserted into holes through the web of each rail, the slotted ends of the terminals being spread over the rail by means of a hammer and a specially-constructed punch. Steel drift-pins, $\frac{1}{16}$ inch larger in diameter than the holes in the terminals, are then driven in, thus permanently expanding the metal of the bond against the sides of the holes, and ensuring electrical contact between the two metallic surfaces. The Neptune bond is a German bond, similar to the Chicago bond, and is fixed in the same manner. Chicago Crown bonds are made in several different forms, and are considered an improvement on the Chicago bond. They consist of copper wires stranded together,

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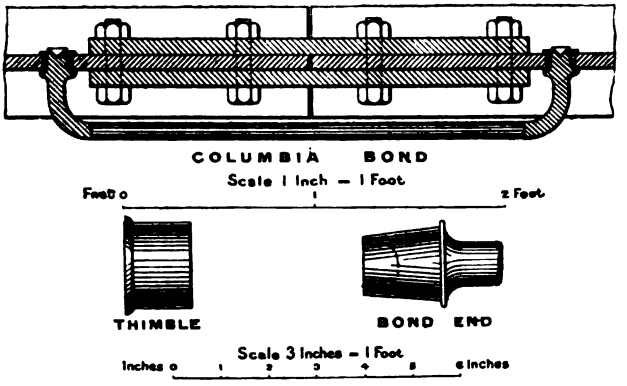
with terminals similar to those of the Chicago bond, the strands and terminals being welded together. They are made either flat or round, are quite flexible, and are fixed with steel drift-pins either in the flange of the rail or between the rail and the fish-plate, or over the fish-plate. The Columbia bond (*Figs. 19*) consists of three parts, two copper thimbles and a solid copper connecting-rod. The rod has a truncated cone-shaped head with a fillet at the base at each end, and the inside of the thimbles is shaped to suit the head, and slightly tapered the opposite way on the outside. The heads are placed through the holes in the rails from one side, and the thimbles are placed over them from the other side, and then firmly forced into contact by means of a hand-press. The Glover horse-shoe flexible bond is similar to some forms of the Chicago Crown bond, and is fixed in the same manner, usually in the flange

Figs. 19.



of the rail. Before applying the bonds, except in the case of the Edison-Brown plastic bond, the holes in the rails and castings are reamed out to the required size and cleaned to a bright metallic surface, and the terminals of the bonds are burnished with a flat file or emery cloth before insertion. When fixed the bonds are painted with one coat of special varnish.

Plastering Rails.—It is customary with some engineers to fill up the space on each side of the web with a mixture of 1 of lias lime or cement and 4 of sand; but, unless it be to save pitch-grouting, the Author does not see the use of thus plastering the rails. After the paving-setts have been laid, this space is racked and grouted along with the joints of the paving.

Paving.—The setts most commonly employed for paving tramways are those of granite, whinstone, or wood. Stone setts should

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be of first-class quality of material, square-dressed throughout, presenting rectangular faces, with practically straight edges, accurately gauged, the maximum variation allowed being ¼ inch. They should be laid close up to the rails on a bedding of sand, both the side and end joints being kept as close as possible. With a 7-inch rail, setts not more than 6 inches in depth should be used, in order to allow of at least ½ inch of bedding between the bottom of the sett and the rail-flange, and they should be 3½ inches to 4 inches in thickness, and 6 inches to 10 inches in length. The setts for paving on steep gradients should only be 3 inches, in thickness in order to ease, to a certain extent, the strain thrown on a horse by slipping from one joint to another, and the joints, when finished, should be grouted only to within ¾ inch of the upper surface of the setts, to provide a better foothold for horses. Wood blocks are either of Karri or Jarrah hardwood, or of creosoted beechwood, the latter being less expensive but not so durable. They should be cut perfectly rectangular, 3 inches in thickness and 6 inches to 10 inches in length, of the required depth, and are laid on the prepared concrete without bedding, or on a thin layer of cement, close jointed, or with spaces between the courses not exceeding ¼ inch. When wood blocks are laid with close joints they are sometimes dipped into boiling pitch-bitumen immediately before being laid. In some cases, where the wood paving extends over the whole width of the street, ¾-inch joints filled with clay are made alongside the curb on each side to allow for the expansion of the wood. Wood paving should not be laid on a gradient steeper than 1 in 20. Basalt-lava setts, which have recently been introduced for tramway paving, are rapidly coming to the front in public favour. Being noiseless and non-slipping, they are likely to supersede wood blocks, which have to be frequently sanded during wet weather to prevent horses slipping on them. When a tramway is laid in a macadamized road, the tramway margins should be paved with a straight joint abutting the macadam, instead of being toothed, as this allows of the disturbed macadam being rolled close up to the paving without damage to the latter. In the Isle of Thanet some parts of the tramways are paved with toothed granite margins on each side of the rail, with macadam between the margins. This construction, however, is not to be commended, as, apart from the certainty of the macadam wearing much more quickly than the granite margin, reliance has to be placed solely on the tie-bars to keep the gauge true and the rails from springing. This also applies to other pavings, such as asphalt, tar-macadam, etc. Macadamized roads, too, in dry

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weather, get very dusty, and would thus be liable to interfere with the mechanism of the cars, whilst asphalt and similar pavings are apt to crack owing to the vibration of the cars, and thus allow water to get down to the foundation. In stone paving, the cross-fall from the outside rail to the channel should not be steeper than 1 in 15, whilst for wood paving the gradient should not exceed 1 in 25. The paving between rails should be laid with ¼ inch of camber at the centre. The joints of stone paving are racked with small broken granite or other hardstone chippings, free from dust, to pass through a ½-inch riddle, and the setts are thoroughly beaten with a rammer to an unyielding bed, after which more chippings are added until the joints are nearly full. With wood paving, small clean gravel, to pass through a ¼-inch riddle, and to be retained by an ⅛-inch riddle, should be used for racking.

Grouting.—Both cement grouting and pitch grouting are used for tramway paving, the latter being more generally employed, as it is specially adapted for the purpose, on account of its elasticity. Pitch grouting should be manufactured from pure gas-tar, pitch, and creosote oil, in the proportion of 1 ton of pitch to 80 gallons of tar, and 20 gallons of creosote oil, or such modification thereof as may be found necessary. The setts should be quite dry before being grouted. The joints of the setts and the spaces between the setts and the rails are filled to within ½ inch of the surface with pitch grouting, applied at boiling point, to ensure its penetration to the bottom of the paving, and the paving is again grouted flush with the surface, with a mixture of 1 of cement or lias lime and of sand. This prevents the pitch grouting running over into the grooves of the rails during hot weather. When completed, the whole of the paving is covered with a layer of coarse sand not less than ¼ inch in thickness.

Estimate of the Cost of Construction per Mile of Single Track.—An estimate of the cost for a mile of single track, exclusive of passing-places, to 4 feet 8½ inches gauge, laid in a road already paved, with sole-plate joints, paved with 6-inch granite setts to the usual tramway limits, cross-bonded every 200 feet and with two bonds at each joint, is given in the Appendix. The cost will vary according to the quality of the materials used, the method of construction, and the locality.

Particulars of rails, fish-plates, tie-bars, etc., and of the sharpest curves and steepest gradients of the majority of the electric tramways in this country are given in the Appendix, and the Author desires to thank the various engineers who have supplied him with this information.

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In conclusion, the Author desires to express his indebtedness to Mr. S. S. Platt, M. Inst. C.E., Borough and Tramway Engineer, Rochdale, for the use of Papers and drawings; to Messrs. Hadfield's Steel Foundry Company, Limited, Sheffield, for information and drawings; and to Messrs. Askham, Brothers, and Wilson, Limited, Sheffield, for the use of drawings; all of which have greatly assisted him in the preparation of the foregoing Paper.

The Paper is accompanied by eight sheets of drawings, from which the Figures in the text have been prepared, and by the following Appendix.

[APPENDIX.

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APPENDIX.

TABLE I.—ESTIMATE OF THE COST OF CONSTRUCTION PER MILE OF SINGLE TRACK.

Description.	Quantity.	Rate.	£	s.	d.
Steel girder rails, 6½ by 6½ inches, 60 feet in length, weighing 95 lbs. per yard per ton	150	£6 15*s.*	1,012	10	0
172 pairs fish-plates, 50 lbs. per pair per ton	3·84	£7	26	17	7
2½ lbs. bolts and nuts for fish-plates per ton	1·04	£16 17*s.* 6*d.*	17	11	0
Tie-bars, with nuts and washers, 14 lbs. each, spaced 7 feet 6 inches centre to centre (notched at one end) . per ton	4·4	£10	44	0	0
Steel sole-plates at joints with fixings each	172	9*s.*	77	8	0
60½-inch copper bonds . . per 100	26	£20	5	4	0
35-inch copper-joint bonds . per 100	344	£13 5*s.*	45	11	7
Lifting, cleaning, carting and stacking separately old setts, average distance not exceeding 1 mile per square yard	4,700	9*d.*	176	5	0
Excavation carted away per cubic yard	915	2*s.*	91	10	0
Portland-cement concrete foundation 6 inches deep . . . per cubic yard	785	18*s.*	706	10	0
Laying tramway, including moving metals into position, fixing, gauging, levelling, packing, and bedding rails, etc. . . . . per lineal yard	1,760	2*s.*	176	0	0
Supplying and fixing temporary iron gauge-rods . . . . . allow	..	..	5	0	0
Fixing and painting bonds . . each	370	1*s.*	18	10	0
Paving with new granite setts, 6 inches deep, bedded on sand, racking with granite chippings, and covering off with ¼ inch of sand after being grouted per square yard	4,360	10*s.*	2,180	0	0
Tusking and coursing setts alongside of track . . . . . per lineal yard	3,520	6*d.*	88	0	0
Grouting joints of setts with pitch bitumen . . . . . per square yard	4,360	1*s.*	218	0	0
Packing spaces between each side of rail and setts with granite chippings, and grouting with pitch bitumen . . . per lineal yard of rail	3,520	6*d.*	88	0	0
Fencing, watching and lighting . . . . . allow			60	0	0
Taking delivery of materials and watching and lighting same allow			100	0	0
Adjusting manholes, lampholes, restoring mains, water- and gas-pipes, etc. . . . . allow			50	0	0
Protection from weather, tarpaulins, etc. . . . . allow			10	0	0
Removing surplus and waste materials . . . . . allow			20	0	0
	Total . . .		£5,216	17	2

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TABLE II.—PARTICULARS OF RAILS, FISH-PLATES, TIE-BARS, ETC., SHARPEST CURVES AND STEEPEST GRADIENTS OF ELECTRIC TRAMWAYS, IN GREAT BRITAIN AND IRELAND.

—	Gauge.	Length of Rail.	Weight per Yard of Rail.	Dimensions of Rail in Inches.	Length of Fish-Plates.	Weight per Pair of Fish-Plates.	Space Between Tie-bars.	Dimensions of Tie-bars.	Sharpest Curve.	Steepest Gradient.
	Ft. Ins.	Feet.	Lbs.	Depth. × Base.	Inches.	Lbs.	Ft. Ins.	Inches.	Feet.	
Aberdeen	4 8½	60	97	7 × 6	31	75	5 0	2½ × ⅜	58	1 in 28
Ayr	4 8½	45	90	6½ × 5⅜	24	50	7 6	2 × ⅜	45	1 „ 22
Birkenhead	4 8½	60	100	7 × 7	24	54	10 0	2 × ⅜	45	1 „ 13·5
Birmingham	3 6	45	98	7 × 7	24	70	9 0	2 × ⅜	44	1 „ 20
Blackburn	4 0	45	92½	6 × 7	24	57	10 0	2 × ⅜	33	1 „ 16
Blackpool	4 8½	60	95	4½ × 5	None	None	6 0	2 × ½	38	None.
Bolton	4 8½	60	105	7 × 7	26	68	7 0	2 × 7/16	35	1 in 17
Bradford	4 0	36	105	7 × 7½	36	88½	15 0	1¼ × ⅜	38	1 „ 14·25
Brighton	3 6	36	101	6 × 7	24	46	..	2½ × ⅜	40	1 „ 9
Bristol	4 8½	..	92	6 × 7	..	..	..	2 × ⅜	33	1 „ 15
Carlisle	3 6	40	83	6 × 6	24	50	7 6	2 × ⅜	40	1 „ 14
Cheltenham	3 6	32	83	6⅝ × 6	26	65	10 0	2 × ⅜	..	1 „ 10
Cork	2 11½	30	85	6⅝ × 6	26	56	9 0	2 × ⅜	28½	1 „ 14
Coventry	3 6	45	84	6 × 4	None	None	10 0	1½ × ⅜	None	1 „ 12
Darwen	4 0	60	92	7 × 7	24	60	7 6	2 × ½	35	1 „ 9
Devonport	3 6	45	95	6½ × 7	24	50	8 2	2½ × 7/16	30	1 „ 11
Dover	3 6	30	87	6½ × 6	20	64	8 0	2 × ⅜	42	1 „ 25
Dublin	5 3	40	92	7 × 7	28	65	8 0	2 × ⅜	36	1 „ 12·37
Dundee	4 8½	45	93	7 × 6½	20	52	8 0	2 × ⅜	35	1 „ 11
East Ham	4 8½	40	90	6½ × 6	27	65	8 0	2 × ⅜	40	1 „ 30
Farnworth (Lancs.)	4 8½	60	98	7 × 7	24	57½	7 6	2 × ⅜	36	1 „ 31·53
Gateshead	4 8½	45	90	6½ × 5⅜	19	89	8 0	.. ..	36	1 „ 8
Glasgow	4 7⅜	60	98	7 × 7	31	74	5 0	2 × ⅜	35	1 „ 14
Greenock	4 7⅜	45	90	6½ × 5⅜	19	41	8 0	2 × ⅜	40	1 „ 14
Halifax	3 6	60	100	7 × 7	24	60	8 0	2 × ⅜	30	1 „ 9·70
Huddersfield	4 8½	60	98	7 × 7	32	74	10 0	2 × ⅜	30	1 „ 11
Hull	4 8½	60	94	6 × 7	24	46½	6 0	1½ × ⅜	30	1 „ 30
Isle of Thanet	3 6	30	83	6⅝ × 6	24	56	7 6	2 × ⅜	40	1 „ 11

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TABLE II.—*Continued.*

—	Gauge.	Length of Rail.	Weight per Yard of Rail.	Dimensions of Rail in Inches.	Length of Fish-Plates.	Weight per Pair of Fish-Plates.	Space between Tie-bars.	Dimensions of Tie-bars.	Sharpest Curve.	Steepest Gradient.
	Ft. Ins.	Feet.	Lbs.	Depth. × Base.	Inches.	Lbs.	Ft. Ins.	Inches.	Ft. Ins.	
Kidderminster	3 6	..	75	7 × 7	25	..	..	..	..	1 in 14
Leeds	4 8½	60	100	7 × 7	24	47	10 0	2½ × ½	50 0	1 „ 21
Liverpool	4 8½	60	95	7 × 7	24	62	10 0	2½ × ¼	35 0	1 „ 14
London United	4 8	36	92½	6 × 7	24	92½	..	..	..	..
Manchester	4 8½	60	100	7 × 7	24	64	10 0	2 × [illegible]	30 0	1 „ 20
Middlesbrough	3 6	36	92½	6 × 7	None	None	10 0	2 × [illegible]	30 0	1 „ 18
Newcastle-on-Tyne	4 8½	60	100	7 × 7	32	120	12 0	2 × [illegible]	37 7½	1 „ 13
Norwich	3 6	45	65½	6 × 4	None	None	10 0	1½ × [illegible]	35 0	1 „ 14·50
Nottingham	4 8½	60	107	7 × 7	31	77½	5 0	2 × [illegible]	50 0	1 „ 14
Oldham	4 8½	45	100	7 × 7	24	123	9 0	2 × [illegible]	40 0	1 „ 10·50
Oldham, Ashton and Hyde	4 8½	33	94	..	..	..	..	..	..	1 „ 11
Plymouth	3 6	60	92	7 × 7	24	48	9 0	2 × [illegible]	33 0	1 „ 14
Poole and district	3 6	45	90	6¾ × 5½	19	39	4 0	2 × [illegible]	40 0	1 „ 13
Portsmouth	4 7¾	40	96	7 × 7	24	130	8 0	2 × [illegible]	35 0	1 „ 17
Potteries	4 0	30	87	6½ × 6	20	..	8 0	2 × [illegible]	..	1 „ 8·60
Rochdale	4 8½	60	103	7 × 7	27	53	7 6	2 × [illegible]	50 0	1 „ 12
Salford	4 8½	60	103	7 × 7	27	73½	7 6	2 × [illegible]	42 6	1 „ 20
Sheffield	4 8½	30	108½	7 × 7 7/16	36	80	10 0	2 × [illegible]	36 0	1 „ 10
Southampton	4 8½	45	86	6 × 6	24	34½	7 0	2½ × [illegible]	None	
Southend-on-Sea	3 6	45	93	6½ × 6	19	38	8 0	2½ × [illegible]	50 0	1 „ 18
Southport	4 8½	40	87	6⅝ × 6	24	..	10 0	2 × [illegible]	45 0	None
South Staffordshire	3 6	30	74	6 × 6	16	28	9 0	1½ × [illegible]	35 0	1 „ 16
St Helens	4 8½	45	95	7 × 7	24	60	7 6	2 × [illegible]	36 0	1 „ 13
Stockport	4 8½	60	95½	7 × 7	24	65	10 0	2 × [illegible]	35 0	1 „ 15·90
Sunderland	4 8½	40	96	7 × 7	24	64	8 0	2 × [illegible]	40 0	1 „ 12
Swansea	4 8½	36	86	6 × 6	24	40	8 0	2½ × [illegible]	40 0	1 „ 22
Taunton	3 6	45	91	6½ × 5¼	19	40	8 0	2½ × [illegible]	45 0	1 „ 25
Wigan	3 6	60	107	6 × 6	24	40	8 0	2½ × [illegible]	40 0	1 „ 12·90
Wolverhampton	3 6	60	91	6½ × 6½	24	61	6 0	2 × [illegible]	37 6	1 „ 20

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OBITUARY.

FIELD-MARSHAL SIR JOHN LINTORN ARABIN SIMMONS,[1] G.C.B., G.C.M.G., Royal Engineers, died on the 14th February, 1903, at Hawley House, Blackwater, Hants. He was the fifth son of the late Captain Thomas Frederick Simmons, Royal Artillery, a well-known authority on Military Law, whose book on the "Constitution and Practice of Courts-martial" was for many years the standard treatise on the subject. Lintorn Simmons was born at Langford, in Somerset, on the 12th February, 1821, and after being educated at Elizabeth College, Guernsey, and at the Royal Military Academy, Woolwich, obtained his first commission as a second lieutenant, Royal Engineers, in December, 1837. His early service was in North America; and for the first portion of his professional career he devoted his attention largely to railway work, holding successively the appointments of Inspector of Railways, Secretary to the Railway Commission, and Secretary to the Railway Department of the Board of Trade. In 1853, however, his presence, on leave, in Turkey led to his employment by Lord Stratford de Redcliffe on several important missions connected with the Embassy at Constantinople. This was followed by the appointment of Captain Simmons as Her Majesty's Commissioner at the headquarters of the Ottoman army in Europe, which post he retained until 1857, having in the meantime obtained promotion by two brevets to the rank of Lieutenant-Colonel.

In the spring and summer of 1854 Simmons served with the army under Omar Pasha and in the operations on the Danube, and was present at the siege of Silistria, which, although Von Moltke accounted it the worst of the Danubian fortresses, has repeatedly played an important part in Russo-Turkish wars. In 1854 the defences had been renovated, and, under the leadership of several British officers, they were brilliantly and tenaciously held by the Turks. After pressing the siege with great vigour, the Russians were forced, on the 22nd June, to raise it and to recross the Danube. For his services in the Danube campaign Simmons

[1] This notice, with some slight modification and addition, is reprinted from *The Times* of the 16th February, 1903.

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received the Turkish gold medal, with an additional medal for Silistria. In December, 1854, having become a major by brevet, he proceeded to the Crimea, where he took part in the siege of Sevastopol, and was present at the action of Eupatoria on the 17th February, 1855. For some time previously a cordon of Russian cavalry had surrounded Eupatoria, which was held by a Turkish garrison from Omar Pasha's army. On the 17th February the Russians made a determined attack on the town with 40,000 of all arms, but were repulsed, leaving nearly 500 dead. The Turkish garrison, with which Major Simmons served, lost 97 killed and had nearly 300 wounded. For his services in the Crimea, Simmons received, in addition to a brevet and a mention in despatches, the C.B., the third class of the Medjidieh—of which he afterwards had the Grand Cordon—the fifth class of the Legion of Honour, and a sword of honour from the Sultan. Later, in 1855, he accompanied Omar Pasha to Asia Minor, and was present at the action on the River Ingur, where he rendered notable service by leading a column across the river, turning the Russian position, and capturing the enemy's works and guns. This ended a war record which, although brief, was full of distinction, and would only have been possible in the case of a man of great tact and *savoir faire*, as well as of marked military talent and many-sided ability.

During 1857 Colonel Simmons acted as British Commissioner for the regulation of the Russo-Turkish boundary in Asia, and from 1858 to 1860 he served as Consul-General at Warsaw. At the close of 1860 he was given the command of the Royal Engineers at Aldershot, and five years later was appointed Director of the Royal Engineer establishment at Chatham, where he remained until his promotion to Major-General in 1868. In 1869 he was created a K.C.B., and made Lieutenant-Governor of the Royal Military Academy, Woolwich, becoming Governor in the following year. Among the cadets at the "Shop" during the earlier period of Sir Lintorn Simmons's direction of that establishment were two who have risen to peculiar distinction as Royal Engineer officers—namely, Lord Kitchener of Khartum and Major-General Sir Herbert Chermside.

In 1871 Sir Lintorn Simmons published an important pamphlet, of which probably very few copies now exist, on "The Military Forces of Great Britain." In this luminous and forcible *brochure* he argued that the existing system of a small army with partially-trained reserves of Militia, Volunteers, &c., did not and could not possibly afford such a military force as was requisite. After considering the Continental systems, he deprecated the idea that even

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the Swiss plan of modified conscription, then being widely advocated, would produce adequate results in this country, for which a force more highly trained than the Swiss Militia was, he thought, a necessity. In view of the changes that have since taken place, and of further changes that are being suggested as regards the military system of the country, it is interesting to note that the late Field-Marshal, so far back as 1871, was warmly in favour of enlisting men between the ages of 20 and 24 by voluntary enlistment, on clear and intelligible terms, offering a fair day's pay for a fair day's work, for periods of three years in the infantry and six years in the cavalry, Artillery and Engineers. The men so enlisted, to the number annually of about 40,000, were to form the standing Army, and to be liable to additional service so long as required during war, if such occurred during their period of service with the colours. A Reserve was provided for, but on voluntary lines, and three years' men were to be encouraged to volunteer for a six years' period of Indian and colonial service. The lapse of years has naturally deprived the scheme of much of its original weight; but there are several points in it which may yet be studied with advantage; and the pamphlet indicates the author's clear and vigorous perception of contemporary military deficiencies.

After six useful years spent in directing the studies at the Royal Military Academy, Sir Lintorn Simmons, now a Lieutenant-General, was appointed in 1875 Inspector-General of Fortifications, in which extremely important post he remained until 1880. In the meantime, however, he had performed excellent service in several public capacities outside the Army headquarters staff. In 1874 he served on the Royal Commission on Railway Accidents, a duty for which his early railway experience specially qualified him. In 1878 he achieved the greater distinction of being attached to the Special Embassy during the Berlin Congress. In 1879 he served on the Colonial Defence Commission, and in 1880 he was specially appointed to assist Lord Odo Russell at the Berlin Conference on the Greek Frontier question. His seniority—he had become full General in 1877—now restricted the area of his military employment; but in 1884 a fitting post was found for him in the Governorship of Malta, which he was enabled to hold until 1888, when he was retired under the age rule which forbids the employment of army officers after reaching 67. The last public service rendered by this distinguished veteran was as Envoy Extraordinary and Minister Plenipotentiary to the Pope in 1889. In May, 1890, Sir Lintorn Simmons, who had been created a G.C.B. in 1878 and a G.C.M.G. in 1887, was given the bâton of a

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Field-Marshal, in which rank he had been senior of those not of Royal blood for several years before his death.

Sir Lintorn Simmons was twice married—first, in 1846, to Ellen, daughter of Mr. John Lintorn Simmons, of Keynsham, secondly, in 1856, to Blanch, daughter of Mr. Samuel Charles Weston, who died in 1898.

Sir Lintorn Simmons at the time of his death, was one of the senior members of the Institution. He was elected an Associate on the 1st June, 1847, and an Honorary Member on the 1st March, 1892.

JOHN ADDISON, born at Liverpool on the 12th April, 1820, belonged to a family who had lived for many generations at Upper Teesdale. Early in life he showed a taste for engineering work, and during the development of the railway system throughout the country adopted that profession. He was educated at Darlington. At the age of 10, when staying in Liverpool, he was present at the funeral of Mr. Huskisson, M.P., who was killed at the opening of the Liverpool and Manchester Railway, and this great demonstration of public feeling made a lasting impression n his mind.

On leaving school in October, 1836, Mr. Addison was articled to Mr. Stephen Robinson of Hartlepool, where he acquired some experience in railway and dock construction, and during the latter part of his pupilage he was employed as Resident Engineer on the Clarence and Hartlepool Junction Railway then in course of construction. After this he spent about a year at the Hartlepool Engineering Works in order to gain some knowledge of the mechanical branch of the profession. During the years 1839 and 1840 he lectured on surveying, levelling and mechanical drawing to the newly-formed engineering class at Durham University. In 1842 he entered the office of Messrs. John and Benjamin Green, Architects and Civil Engineers of Newcastle-on-Tyne, but was soon afterwards engaged by Mr. John Blackmore, the Engineer of the Newcastle and Carlisle Railway, as Chief Assistant, in which capacity he conducted the business of Mr. Blackmore, whose health had failed.

On the death of Mr. Blackmore in March 1844, Mr. Addison was appointed to the staff of Messrs. Locke and Errington, who were at that time the engineers of lines about to be constructed from Lancaster to Carlisle, in extension of the London and North-

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Western system, and from Carlisle to Edinburgh, Glasgow, Perth, Forfar, on the Caledonian Railway. In that capacity he ran one of the first lines of levels over Shap Fells and afterwards prepared the working section of the Lancaster and Carlisle line. He was subsequently employed by Messrs. Locke and Errington on the Parliamentary surveys of the Shrewsbury and Stafford, the Shrewsbury and Wolverhampton, the Hayton and Warrington, the Runcorn Gap and other lines.

During the memorable Parliamentary contest between the Caledonian and the Glasgow and South-Western Railway Companies in 1845, Mr. Addison was sent on behalf of the former Company to survey a line through the Dalveen Pass connecting Thornhill on the Glasgow and South-Western Railway with Elvanfoot on the Caledonian Railway; the Parliamentary Committee desiring to have a report as to whether the two railways could be combined. The report being hostile to that theory resulted in the Caledonian Railway, for which Mr. Addison was engaged, obtaining their Act.

Mr. Addison was then appointed Resident Engineer on the Southern division of the new Railway (the Caledonian), and, after preparing the working sections of the first 60 miles from Carlisle northwards, superintended the construction of the first 30 miles, on which is the first railway bridge uniting England with Scotland. Between 1845 and 1848 he surveyed several lines promoted by the Caledonian Company to Annan, Dumfries, Cannobie, Langholm and Brampton, and gave engineering evidence before Parliamentary Committees against sundry hostile schemes projected by other companies.

The financial crisis of 1847 and 1848 brought a great strain to bear on the working powers of the Caledonian staff. The public began to lose faith in the rapid development of railway enterprise. Bankers and capitalists hesitated to advance more money except on the personal guarantee of the directors, thus placing the promoters of the Caledonian Railway in great difficulties. Happily the credit of the Company was to a great extent restored by the opening of the line from Carlisle to Beattock on the 10th September, 1847, and was quite established when the railway through to Edinburgh and Glasgow was opened on the 15th February, 1848.

Mr. Addison often referred to this event as one of the greatest interest and excitement. He remained on the engine of the first train that travelled from Carlisle to Edinburgh throughout the journey of sixteen hours, when in several places temporary rails

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had to be laid in order to enable them to pass over the unfinished sections of the line; but the result, namely, the arrival of the little train in Edinburgh, at once restored confidence to the minds of capitalists, for till then the public had grave doubts as to whether it was possible for a locomotive steam-engine to draw a train of carriages over "Beattock summit," namely, the heavy gradient to the north of Moffat. It was on the 30th September, 1848, that Queen Victoria made her first railway journey to Scotland, and this was by the Caledonian line.

In December, 1857, after having served the Caledonian Railway Company for upwards of twelve years as Resident Engineer and subsequently as Superintendent of the line, Mr. Addison undertook the management of the Maryport and Carlisle Railway, being appointed head of its several departments. He retained that post for twenty-seven years during the most prosperous period of the Company's existence, and then declining health compelled him to retire from active official life on the 1st March, 1884, at the age of 64. On his retirement he was appointed a Director of the Maryport and Carlisle Railway Company.

Mr. Addison always took keen interest in matters relating to the welfare of the district in which he lived. He commanded the Maryport Artillery Volunteers from the year 1860 to 1865. In 1877 he was appointed a trustee of the District and Harbour of Maryport, and in October of the same year he was placed on the Commission of the Peace for the County of Cumberland. He married in 1845 the younger daughter of the late Mr. John Green, of Newcastle-on-Tyne, Architect to the Duke of Northumberland.

Mr. Addison died at his residence, The Castle Hill, Maryport, on the 22nd March, 1903, in his 83rd year.

He was elected an Associate of the Institution on the 2nd March, 1847, and was transferred to the class of Members on the 1st February, 1859.

THOMAS MORRISON BARR, born in Glasgow on the 29th April, 1834, obtained his preliminary engineering training first as a pupil and subsequently as an Assistant of the late Mr. Thomas Kyle, under whom he made a survey of the Clyde and took soundings of that river between Glasgow and Port Glasgow, in preparation for the Act constituting the Clyde Trust. In 1860 he became Chief Assistant to Messrs. Wylie and Peddie, of Edinburgh, for whom he was engaged on work in connection with the railway from Peebles to Innerleithen and on the Kirkcudbright and

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the Berwickshire lines. He acted as Resident Engineer on the construction of the Kirkcudbright line, and had charge of that line until it was amalgamated with the Glasgow and South Western Railway in 1865. Mr. Barr was then appointed to the Engineer's staff of the latter railway, and in the winter of 1868 he inspected the whole of the Company's system and made a report on the permanent way.

In 1871 Mr. Barr entered the service of the Caledonian Railway Company as Assistant to the late Mr. George Graham, for many years Chief Engineer to that Company, and was engaged in designing and superintending the carrying out of new branch lines, the extension and renewal of stations, and other works, chiefly in the Glasgow district. On a redistribution of the duties of the engineering staff in 1880, Mr. Barr was appointed Engineer of the Northern Division, comprising about 350 miles of railway, and including the Callander and Oban line and all lines north of Greenhill to Aberdeen, and from Arbroath and Dundee to Oban. Within the last twenty years about sixty viaducts and bridges in the Northern Division have been renewed under his superintendence, while about thirty stations have been reconstructed. Mr. Barr retired from the Company's service on the 31st January, 1902, and died at his residence, Willowbank, Barnhill, Perth, on the 11th February, 1903.

He was elected a Member of the Institution on the 7th February, 1882.

WALTHEW CLARANCE BARTON, born on the 29th August, 1834, at Dartford, Kent, entered the Public Works Department of the Government of India in 1855 as a Covenanted Civil Engineer. After being employed for six years as an Assistant Engineer in the Bombay Presidency, and for two years as Executive Engineer in charge of the district of Ahmedabad, he was transferred in 1863 to Travancore, and appointed Chief Engineer of that province in 1873.

As head of the Public Works Department of that important state, Mr. Barton had to contend at the very outset with difficulties from want of trained subordinates, skilled labour, and facilities of every description. These difficulties, however, were overcome by his powers of organization, and by the zeal and energy he brought to bear upon his work. He opened up the country in every direction with a well-devised network of roads extending

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from the Ghauts to the seaboard, by which transport was facilitated and cheapened, and vast tracts of inaccessible forest and waste land were opened to habitation and cultivation. Dangerous and impassable rivers were bridged, works of irrigation and inland navigation were carried out, and the capital, Trivandrum, was supplied with good roads and with suitable public offices, courts, schools and hospitals.

Mr. Barton retired from the service of the Travancore State in 1880, from which time he ceased, owing to ill health, to undertake professional work. He died at Ilkley, Yorkshire, on the 16th January, 1903, at the age of 68.

Mr. Barton was elected a Member of the Institution on the 7th April, 1868.

DAVID WILKINSON CAMPBELL, C.I.E., died on the 9th February, 1903, at his residence 55 Esplanade, Greenock, in his 72nd year. Born in November, 1831, he was the youngest son of the late Mr. John Campbell, Comptroller of H.M. Customs, Greenock, and after serving a pupilage in the Locomotive Works of the Caledonian Railway Company, acted as an Assistant Locomotive Superintendent on that line from 1851 to 1858, being for part of that time Works Manager at St. Rollox. In 1858 he obtained the post of Locomotive Superintendent of the South-West Provinces Division of the East Indian Railway, and in 1865 he was appointed Locomotive Superintendent of the whole line. When Mr. Campbell joined the East Indian Railway it was about 200 miles long, and when he left, after 33 years' service, it was 2,000 miles in length. To high professional attainments he added great powers of organization and control. Though a thorough disciplinarian, he was beloved by all his subordinates, both European and native, in whose social and domestic welfare he took the greatest interest. India owes to him a great debt for the training and introduction of natives as engine-drivers, opening a new field of employment for natives and resulting in great economy in the working of all Indian Railways. In 1887 he was promoted to be the Agent of the Company in Calcutta, and in 1891 he retired and, returning to England, settled in Bedford, which he left only a year ago to reside in his native town of Greenock.

Mr. Campbell was a strong supporter of the Volunteer movement, and for many years was Colonel Commanding the East Indian Railway Volunteer Rifle Corps, over 1,000 strong. In 1883 he was created a Companion of the Order of the Indian Empire for

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his services, and was also appointed by Lord Ripon to be an honorary *aide-de-camp* to the Viceroy.

Mr. Campbell was elected a Member of the Institution on the 27th May, 1879.

GEORGE EDWARD GAVEY died on the 3rd January, 1903, at his residence 7 Westbourne Villas, Hove. Born at Vauxhall, St. Helier, Jersey, on the 29th September, 1818, he was the only son of Captain Daniel Gavey, an officer who saw much service in India. After being educated in Jersey and at Coutances in France, the subject of this notice obtained some engineering experience on the harbour works at St. Helier, then being carried out by Mr. James Walker, Past-President. From 1842 to 1845 he travelled on the Continent, visiting Switzerland and the principal towns in Italy and Sicily. On his return in 1845 he was articled to Mr. R. M. Marchant, one of the Resident Engineers on the South Devon Railway, and in the the following year he was appointed by Mr. I. K. Brunel an Assistant Engineer on a section of the Oxford, Worcester and Wolverhampton Railway, between the towns of Dudley and Stourbridge. In the construction of Mickleton Tunnel in Gloucestershire, on the same line, which he afterwards superintended, his abilities were put to the test, as, owing to the quicksands met with, the work was one of considerable difficulty.

In 1852 Mr. Gavey accepted the appointment of Resident Engineer on the Earl of Dudley's extensive estates in Staffordshire. He was subsequently appointed Resident Engineer on the Salisbury branch of the Wilts, Somerset and Weymouth Railway, under Mr. Brunel, the work on which line included the construction of two viaducts and four stations, one being the large terminus at Salisbury. In 1856, through Mr. Brunel's influence, he received the appointment of Resident Engineer on a heavy section of the Great Luxemburg Railway, under the Engineer-in-Chief of that line, the late Mr. P. P. Baly. Some twelve months afterwards Mr. Baly deputed Mr. Gavey to proceed to Russia as his representative and engineer, with instructions to make all the necessary arrangements relative to the laying out of the Moscow and Saratov Railway, a line of 465 miles. The concession was obtained, but owing to financial difficulties the works could not be commenced, and Mr. Gavey returned to England in 1859. From 1860 to 1864 he was engaged for the late Mr. Charles Vignoles as a Resident Engineer on the Miranda, Tudela and Bilbao Railway in Spain.

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In 1864 Mr. Gavey was appointed principal Resident Engineer on the European Central Railway, between the towns of Como and Biasca, a distance of 60 miles, now forming part of the San Gothard Railway. A few months later he was nominated the representative of the Company in Switzerland, which involved a large amount of secretarial work and constant correspondence with the Government. In 1867 the Board of Directors appointed him Engineer-in-Chief of the Company. The works on that line were very considerable, comprising eight tunnels, two viaducts, several large bridges, and heavy retaining walls, one of them being nearly 2 miles in length. Financial difficulties in 1867 obliged the Company to wind up its affairs in the Court of Chancery, and he was appointed by that Court to act as representative of the Official Liquidator, which office he held until 1872.

At the commencement of 1873, Mr. Gavey was instructed by Mr. R. F. Fairlie, Consulting Engineer to the Venezuelan Government to proceed to Venezuela, and to lay out a narrow-gauge railway for the Government, between La Guayra and Caracas. He also made a survey of the coast line from La Guayra towards Puerto Cabello, between 40 and 50 miles, to ascertain whether a more commodious port than that of La Guayra might be constructed. He returned to England towards the end of 1873 to recruit his health, which had suffered from the hot climate on the coast.

In 1879 he superintended the pipe-laying and part construction of the Waterworks of the City of Truro, and in March 1881, Mr. J. F. La Trobe Bateman, Past-President, instructed him to superintend the drainage of Littlehampton, and in the following year appointed him a Resident Engineer on the Government Water and Drainage Improvement Works at Buenos Ayres. Mr. Gavey completed his engagement there in 1886, from which time he lived in retirement.

Mr. Gavey became a Freemason in 1852 at Stourbridge. In addition to professional work, he took great interest in geology, and was elected a Fellow of the Geological Society in 1850. He discovered many fossils, one of which was named after him. During the latter part of his life his chief hobby was microscopic work. In private life he was much endeared to all who knew him by his courteous and gentle manner, and by his integrity. His conduct was marked by conscientiousness and by a keen sense of duty, which he allowed nothing to influence. Mr. Gavey married in 1853 Miss M. R. Herbert of Edgbaston.

He was elected a Member of the Institution on the 3rd May, 1864.

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NATHANAEL ROBERT GRIFFITH, born on the 21st October, 1847, was the eldest son of Mr. Robert Griffith, a colliery proprietor near Mold. After being educated at private schools and at the Royal School of Mines, of which he became an Associate, he obtained his early professional experience in collieries in the North of England as a pupil of Mr. George Baker Forster. He then undertook the management of his father's colliery, and was subsequently employed at various large collieries in North Wales. In 1876 he was entrusted by the late Mr. Henry Robertson, M.P. for Shrewsbury, with the sinking of the Plas Power Pits and Colliery under the ownership of the Broughton and Plas Power Coal Company, of which Mr. Robertson was Chairman—which became the largest in North Wales. Mr. Griffith was connected with the Company as Consulting Engineer, and afterwards as Director, for the rest of his life. No man was better known in mining circles in North Wales, and he was respected for his remarkable engineering ability, while his generous, kindly disposition made him a general favourite.

Besides being Consulting Engineer to many collieries in North Wales, Mr. Griffith acted in a similar capacity to mines in Italy, Spain, France, Belgium and Norway. He was one of the founders of the North Wales Miners' Permanent Relief Society, and was Chairman of the Board of Management. He was an active member of the Council of the Mining Association of Great Britain, in which capacity he was recently appointed a member of an Advisory Committee in connection with the Home Office inquiry as to the use of electricity in coal-mines. He married in 1868 the fourth daughter of the late Mr. Mortimer Maurice, of Wrexham. Mr. Griffith died at his residence, Wybro House, Wrexham, on the 10th February, 1903, at the age of 55.

He was elected a Member of the Institution on the 6th April, 1897.

EDWARD BEVERSHAM HANSON, son of the Rev. Stephen Hanson of Weeting, Norfolk, was born on the 25th March, 1858, and was educated at Uppingham, Cheltenham College, and the Royal Indian Engineering College at Coopers Hill. After being employed on a practical course on the construction of the Northampton and Rugby section of the London and North Western Railway, he joined the Indian Public Works Department in 1880,

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and was posted to Tanjore. Two years later he returned on sick leave, and subsequently retired from the service. After two short engagements in London in 1883, he was appointed in January, 1884, District Engineer in charge of lines open for traffic on the London Tilbury and Southend Railway, under Mr. A. L. Stride. He held that post until June, 1891, when, after serious illness, he was compelled to resign and to go to South Africa. On the recovery of his health he entered the service of the Public Works Department of Cape Colony in August, 1892.

In 1894 Mr. Hanson returned to England, and for some years practised privately in Devonshire and Cornwall, being engaged principally on light railway work. In August, 1889, he accepted the post of Engineer to Messrs. R. Neill and Sons, of Manchester, on the contract for the widening of the Lancashire and Yorkshire Railway at Bolton, but illness compelled him to relinquish work in October, 1900. He died at Bolton on the 3rd December, 1902.

Mr. Hanson was elected an Associate Member of the Institution on the 1st May, 1883, and was transferred to the class of Members on the 6th March, 1894.

CHARLES LA FLETCHER HILLMAN, born at Albany, New York, on the 19th December, 1835, obtained his early professional experience on the Great Western Railway of Canada. In 1855 he was employed in making preliminary plans and estimates for the Canada Southern Railway and on surveys for a proposed harbour at Two Creeks on Lake Erie; and from 1855 to 1857 he was engaged on the construction of the Detroit and Milwaukee Railway. In the latter year Mr. Hillman went to Chile, where he was employed until 1864, under the late Mr. W. W. Evans, on the construction of the Santiago and San Fernando and the Santiago and Valparaiso Railways. He was next engaged, from 1865 to 1868, on the Tongoy Railway of Chile, and from 1870 to 1876 as Chief Engineer on the Chile Southern Railway, from Santiago to Curico, and on the branch to Palmilla. In 1871 he constructed a portion of the Valparaiso tramway lines, and in 1884, in conjunction with Mr. Stephen Mayers, the railway from Angol to Traiguen, and, in part, that from Renaico to Victoria. Mr. Hillman was a Director of the Santiago Gas Company, and established a factory for the manufacture of matches in Chile. He was frequently consulted on technical matters by the Chilian Government. In 1901 he published, under the pseudonym of "Quien

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Sabe" a book entitled "Old Timers, British and American, in Chile." Mr. Hillman was a Member of the American Society of Civil Engineers. He died at Santiago on the 14th June, 1902.

Mr. Hillman was elected a Member of the Institution on the 4th April, 1882.

CHARLES LE LIEVRE, youngest son of the late Mr. James Le Lievre, was born in Guernsey on the 22nd September, 1848, and commenced his professional training as a pupil of the late Sir Charles Fox, with whom he remained from 1865 to 1869. During that period he was employed on a great deal of important work in London and in the country, among which may be noted the Victoria and Battersea Railways, with the Victoria Bridge over the Thames and the network of viaducts between Victoria and Clapham Junction and Wandsworth Road stations; also surveys for pneumatic railways at Brighton and Manchester. From 1870 to 1874 Mr. Le Lievre was engaged in Canada, first as an Assistant, and afterwards as District Engineer on the Toronto and Nipissing, and the Toronto, Grey and Bruce Railways, under Mr. Edmund Wragge. In February, 1875, he was appointed an Assistant Engineer on the Cape Government Railways, and four years later he was promoted to be a District Engineer, which post he held until August, 1884. During that time he was employed on the construction of the Graaff Reinet Railway, the survey of the Grahamstown and Port Alfred Railway, and the survey and construction of the Craddock-Colesberg Railway and of the Hanover Junction Railway, all of which works were carried out departmentally.

In June, 1888, Mr. Le Lievre accepted an appointment under the Ceylon Government as District Engineer, 1st class. There he was employed, first on the construction of the Haputale Mountain Railway, 5 feet 6 inches gauge, 26 miles in length, with very heavy work, numerous tunnels and several high viaducts. He was also engaged on the construction of the Kurunegala Railway, and subsequently on projects for various lines in the island. He acted for the Chief Resident Engineer, Mr. F. J. Waring, during that officer's absence in England. Mr. Le Lievre left Ceylon in December, 1895, and in the following March he entered the service of the East Indian Railway Company as a Resident Engineer. He did excellent work on the construction of the Moghalserai-Gya line, for which he was specially commended to

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the notice of the Board by the Chief Engineer. He was then placed in charge of the South Behar Railway, and completed the bridge over the Phalgu River at Gya under unusually difficult conditions. In March, 1902, he was placed in charge of the Delhi District of the East Indian Railway—a length of about 400 miles of open line. He was also entrusted with the re-modelling of Delhi station, a work of considerable difficulty with the ordinary traffic, and when to that the special work in connection with the Coronation Durbar was added, his capabilities were severely taxed. His tact in dealing with officers of other departments, his excellent arrangements for carrying out what had to be done, no less than his energy and great capacity for work, enabled him to accomplish successfully more than most men would have found possible. The continuous strain and anxiety, however, proved too much for his constitution; but notwithstanding failing health, and in spite of the warnings of his medical attendant, he determined to remain at his post and endeavour to carry the work through. He died on the 1st January, 1903.

Mr. Le Lievre was elected a Member of the Institution on the 14 April, 1885.

GODFREY OATES MANN was born at Elland, in Yorkshire, in 1829. At the age of 12 he went with his parents to live at Rouen, and in the year 1844 he commenced his engineering career in the locomotive, carriage and general railway plant workshops of Messrs. Allcard, Buddicom and Company in that city, in which works he remained for three years. Leaving France in 1847 he was engaged for a time in the works of Messrs. George Forrester and Company, of Vauxhall Foundry, Liverpool, and in the following year he entered the workshops of the Caledonian Railway, at Greenock, where he remained until 1850. During the latter part of that year he was employed for a few months at Doncaster in the Great Northern Railway Works.

Early in 1851 Mr. Mann was engaged by Messrs. Faviell and Fowler as their Mechanical Engineer and Agent on the construction of the first section of the Great Indian Peninsular Railway, from Bombay to Tanna, on which work he was employed for two years. Leaving India in 1853 he returned to England, and was principal locomotive draughtsman in the works of Messrs. E. B. Wilson and Company, of Leeds, where he remained until 1855, when he was engaged to take out to the Crimea the locomotive

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and stationary engines for the Balaklava Railway, which line he worked successfully until the retirement of the British army in 1856.

At the end of 1856 Mr. Mann was appointed Locomotive Superintendent of the Recife and São Francisco (Pernambuco) Railway. He proceeded to Pernambuco in February, 1857, and after completing the shipping and landing arrangements and the erection of the rolling stock, he designed and superintended the construction of the Company's workshops and of the whole of the plant required during the construction of the line. In 1863 he was appointed the Company's Engineer in Brazil, in addition to holding the post of Locomotive Superintendent, and in October, 1865, he became General Manager of the line. On his retirement in 1875, after eighteen years' service in Brazil, he was elected to a seat on the Board, remaining a Director of the Company until September, 1901, when it went into voluntary liquidation. During his service in Brazil he represented the Company in various difficult and delicate negotiations with the Government of that country and with the provincial administration of Pernambuco, all of which negotiations be brought to a successful issue. His knowledge of French and Portuguese, both of which languages he spoke fluently, was of great use on such occasions.

Since 1875 Mr. Mann lived in retirement, for many years at St. Leonards-on-Sea, where his death took place on the 27th January, 1903.

He was elected a Member of the Institution on the 6th December, 1864. In the previous November he had presented a Paper "On the Decay of Materials in Tropical Climates, and the Methods Employed for Arresting and Preventing it,"[1] for which he was awarded a Telford Premium.

FRANCIS CARR MARSHALL was born at Bedlington, in 1831, and subsequently removed to Newcastle-on-Tyne, where his father was employed at the locomotive works of Messrs. R. and W. Hawthorn at Forth Banks. At the age of 14 the subject of this notice entered Messrs. Hawthorn's works as an ordinary engineering apprentice, passing through the shops, and subsequently into the drawing office. After being employed for some time as a

[1] Minutes of Proceedings Inst. C.E., vol. xxiv. p. 1.

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draughtsman at Forth Banks, he became Chief Draughtsman to the firm of Messrs. Thompson and Boyd, of Newcastle, where he remained until the year 1860, when he was appointed Manager of the engine works of Messrs. Palmer Brothers, at Jarrow. While at Jarrow, the whole of the engine factory was re-modelled and rebuilt under Mr. Marshall's direction, and a large amount of marine-engine work was turned out, including the engines for some of the largest Atlantic liners of that day.

In 1870 Mr. Marshall left Jarrow, and, in association with Mr. (now Sir Benjamin) Browne and others, he purchased the Forth Banks Works of Messrs. R. and W. Hawthorn. In the early "seventies" the firm commenced to do a considerable amount of Government work, with the production of which it has in later years been closely associated. In addition to the Government engines, Mr. Marshall was responsible for the design of a considerable number of large mercantile engines in the early days of the new firm. The works continued to grow and develop until finally it was arranged that the whole of the Marine Department should be moved to St. Peter's, where the boiler yard already was, and Mr. Marshall designed and constructed the present marine-engine works at St. Peter's.

He was prominently associated with the introduction of the high-speed marine-engine for warship work, such as is now commonly in use. In association with Armstrong, Mitchell and Company, he designed and constructed the machinery for small swift cruisers built in 1881–83 for China and Chile. These were followed by the larger cruisers "Esmeralda" for Chile, "Giovanni Bausan" for Italy, and "Naniwa" and "Takachiho" for Japan, built in 1883–85.

Mr. Marshall was also instrumental in introducing the torpedo-boat type of engine and boiler into vessels of larger size, engined by him for the Russian Government and the Italian Government, being the earliest representatives of the torpedo gun-boat class. He was also intimately connected with the introduction of forced draught on board ship.

When the firm of R. and W. Hawthorn amalgamated with Messrs. Andrew Leslie and Company, Mr. Marshall became Managing Director of the engine works. After the amalgamation, he was responsible for a large amount of high-power engines for vessels built at the shipyard, in addition to the warship machinery supplied to His Majesty's dockyards and also to the Armstrong Company. He continued to hold the post of Managing Director at St. Peter's until the year 1897, when, owing to failing health, he

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was obliged to resign active duties, although he remained on the Board of Directors of the Company. For the last few years, however, he was a confirmed invalid, and was not able to take any interest in the business. He died at his residence, Akenside Lodge, Newcastle-on-Tyne, on the 24th February, 1903.

Mr. Marshall was elected a Member of the Institution on the 9th January, 1866.

ROBERT AUGUSTUS OLDHAM, born on the 13th August, 1842, began his engineering career in May, 1862, as a pupil under Mr. W. F. Gooch, at the Great Western Railway works at Swindon. During the two years of his pupilage he worked as a mechanic in the fitters' and carpenters' shops, erecting and running sheds, and finally in the drawing office. This gave him a thorough practical knowledge of the construction and working of locomotive and other engines. In June, 1864, he was articled for a year to Mr. Joseph Mitchell, under whom he was employed first in superintending the construction of the Ross-shire Extension Railway, and subsequently on the survey, sections and bridges of the Sutherland Railway. After the completion of that work he was transferred to the Aberfeldy branch of the Highland Railway. In 1865, he was employed for Mr. George Barclay in making surveys, plans and specifications for a railway in Cornwall, on the completion of which he was appointed by Mr. (subsequently Sir John) Fowler, Past-President, an Assistant Engineer on the St. John's Wood Underground Railway.

In 1866, Mr. Oldham entered the service of the Eastern Bengal Railway Company as an Assistant Engineer. During the following two years he was employed on all descriptions of engineering works connected with the railway, such as maintenance of roads, repair and rebuilding of bridges, besides having charge of 50 or 60 miles of open line.

In January, 1869, with the sanction of the Railway Company, Mr. Oldham was appointed by the Government of India an Assistant Engineer, First Grade, and posted to the Sone Canals in Behar, where he was first employed in constructing a railway of 9 miles to the quarries, in opening up the quarry face, and commencing the head works generally, under the direction of Mr. R. Long, Executive Engineer. He was then instructed to assist Captain J. M. McNeile, R.E., in surveying and drawing up the plans for the extension of the Main Western Canal. After com-

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pleting this he was placed in charge of the Kao sub-division of the Sone Canal, where his work consisted in superintending all the excavations, erection of bridges and buildings, etc.

In March, 1871, Mr. Oldham was promoted to Executive Engineer, Fourth Grade, and after assisting Captain J. M. Heywood, R.E., in completing the plans and estimates of the Arrah Division, he was transferred to the Midnapore Canals, under the immediate orders of Mr. James Kimber, Executive Engineer in charge of the Canals. There he was first employed in getting out the plans and estimates for remodelling the Midnapore weir and head sluices. After this his services were specially applied for by the Eastern Bengal Railway Company to assist in drawing up designs and estimates for new bridges to replace those washed away by the floods of 1871, for submission to Sir John Hawkshaw, the Company's Consulting Engineer in London. On his return from the Eastern Bengal Railway, he was placed in charge of the Experimental Water Distribution Scheme, which he successfully completed about June, 1872. He was then transferred to the Hooghly Investigation Scheme, under the superintendence of Mr. John Whitfield, but was unable to do more than commence this work, owing to his being obliged to take sick leave to England.

On his return to India in September, 1874, Mr. Oldham was specially deputed to draw up the plans and estimates for a navigation canal in Sylhet, under the direction of Mr. John Heyman, Superintending Engineer; and on the completion of that work he was placed in charge of the Backergunge and Furreedpore divisions, the duties of which consisted in looking after and maintaining all the roads and buildings in those districts, together with working out plans and estimates of all new works, and being responsible for the whole of the expenditure in the two districts. In June, 1875, he was transferred to the Gunduck Circle under Mr. T. Martin, Superintending Engineer, and placed in charge of the Lower Gunduck division, a district of some 6,000 square miles. While holding that post he originated and drew up an irrigation project for the Sarun district, which was so strongly recommended by the Government of Bengal that sanction was immediately given, and the work carried out has since fully realized the Chief Engineer's expectations. In September, 1879, he retired from the Government service.

From 1879 to 1890, Mr. Oldham was engaged in private practice on several works of considerable magnitude and importance, among which may be mentioned the preparation of plans and estimates for the Trichinopoly water scheme, which he carried out in con-

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sultation with Mr. James Kimber, then Engineer to the Corporation of Calcutta. The Vellore drainage scheme and the Calcutta eastern suburban water scheme were also carried out by him in consultation with Mr. Kimber. He held the appointment of Engineer to the Receiver of the High Court of Calcutta, and was continually employed by the Administrator-General and other Government officials.

In May, 1890, Mr. Oldham sold his Calcutta business and returned to England, where he found great difficulty in obtaining professional work, and finally invested his savings in a city firm of East India merchants, from which he retired in June, 1898. He died at Edinburgh on the 19th February, 1903, in his sixty-first year.

Mr. Oldham was elected an Associate of the Institution on the 5th December, 1871, and was transferred to the class of Members on the 19th February, 1878.

CHARLES ROBINS, born on the 29th September, 1821, was educated at King's College, London. In 1837 he was articled to the late Mr. John Braithwaite on the Eastern Counties Railway, on which line he acted subsequently as Resident Engineer of the Chelmsford Division. From 1846 to 1850 he was engaged under Mr. Alfred S. Jee and Mr. Herbert F. Mackworth on the Sheffield and Manchester and the Huddersfield and Manchester Railways, on which he designed and carried out many of the heavy viaducts and other works. In 1850 Mr. Robins became Chief Assistant and Manager to Mr. James Samuel, under whom he was engaged until 1874 in carrying out numerous and varied works, among which may be mentioned the Morayshire Railway and extensions, the Newmarket Railway, the Llanelly Railway, the Vale of Towy Railway, the road bridge over the River Avon at Evesham, a 3-foot gauge line in Cape Breton for developing the extensive coal mines in that region, and the Mexican Railway from the port of Vera Cruz to the cities of Puebla and Mexico. He acted for a time as Consulting Engineer to the Mexican Railway, in conjunction with Mr. W. Cross-Buchanan, after the death of Mr. Samuel, during which period they jointly designed and carried out an iron pier at Vera Cruz for that line.

In 1875, Mr. Robins went to Rumania for Messrs. G. B. Crawley and Company, concessionaires and contractors for the Ploisci and

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Predeal Railway and Adjud and Ocna Railway, as Chief Engineer at Bucharest for carrying out those works. Two years later, however, owing to the impending war between Russia and Turkey, the works were stopped. He then accepted the post of Chief Assistant in Dublin to Mr. W. H. Mills, Engineer-in-Chief of the Great Northern Railway of Ireland. During the seven years he held that appointment he prepared the working drawings of several viaducts and bridges, and also of part of the new Dublin Station. In 1885 he retired from professional work. Mr. Robins died at Chester on the 10th February, 1903, in his eighty-second year.

He was elected a Member of the Institution on the 5th February, 1867.

MARTIN SAMUELSON, the son of a Liverpool merchant, was born at Hamburg on the 2nd January, 1825, and served his apprenticeship with the shipbuilding firm of Messrs. Caird, of Greenock, at a time when they were building West Indian mail-packets of wood. After being engaged in the works of Messrs. Hicks, of Bolton, and of Messrs. Sharp, Roberts and Company, of Manchester, and at the Old Ford Waterworks, he was employed for five years, first as an Assistant Engineer and subsequently as Resident Engineer on the construction of railways now forming part of the London and North Western system.

In 1849 he began to practise in Hull as a marine and general engineer under the style of Martin Samuelson and Company. The Company was enlarged in 1854, when his brother, the late Mr. Alexander Samuelson, joined the firm, the chief work being ship-building and the application of steel to marine engineering, as well as the manufacture of hydraulic presses, in place of the old stamper presses, for seed-crushing, the staple industry of Hull. So early as 1856 the firm made steel boilers for use on land. These were for Messrs. Marriott, Atkinson and Company's works at Sheffield, and were in use for twenty years without any material repairs. Mr. Samuelson built in 1860–1862 two early steel vessels, one, the "Annie," being classed after considerable difficulty as "A 1 Experimental" on Lloyd's register; the other, the "Latona," was captured while blockade-running on the coast of America. The firm also built the "Spurn," the "Gertrude" and the "Lord Cardigan," the first cargo steamers to run from Hull to St. Petersburg without having to unload at Cronstadt. During the

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short space of ten years, no less than ninety-seven vessels, principally steamers, were built in the yard. The works were sold in 1864 to the Humber Ironworks and Shipbuilding Company.

Mr. Samuelson then took general engineering works in Neptune Street, Hull, and amongst other work built the North Bridge over the River Hull. This is an hydraulic draw-bridge, which is pulled back into the roadway when required to be opened. He also constructed machinery for the blast furnaces of Messrs. B. Samuelson and Company at Middlesbrough, and travelling rolls for their Britannia Mill, the latter now owned by Messrs. Dorman, Long and Company. This latter machinery was in regular use until 1892, when it was removed and electric power substituted. The works in Neptune Street were sold in 1873 to Messrs. Amos and Smith. Mr. Samuelson then practised as a Consulting Engineer and Marine Surveyor and Valuer, in which capacity he enjoyed a high reputation. He was also Engineer to the Humber Conservancy Commissioners from 1891, and only three days before his death he attended a meeting of that body, when some important proposals made by him for the improvement of the River Humber were considered. Mr. Samuelson was a Member of the Institution of Naval Architects, and was formerly a Member of the Institution of Mechanical Engineers; he was also the first President of the late Hull and District Institution of Engineers and Naval Architects, which was formed in 1885. He was extremely active, even to the day of his death, which took place suddenly at Hessle on the 26th February, 1903. He became a Member of the Town Council of Hull in 1853 and was Sheriff in 1857 and Mayor in 1858. He was the first colonel of the Royal East Yorkshire Volunteer Artillery stationed at Hull, which body he was instrumental in forming. He was a Justice of the Peace for the East Riding of Yorkshire, and Chairman of the Hull Charity Trustees.

Mr. Samuelson was elected a Member of the Institution on the 2nd December, 1862.

JOSEPH MILLER WILSON, son of William Hasell and Jane (Miller) Wilson, was born in Phœnixville, Chester Co., Pa., on the 20th June, 1838. After some preliminary education at private schools he entered the Rensselaer Polytechnic Institute in September, 1854, and having graduated there he studied analytical chemistry for two years with Professor F. A. Genth, of Philadelphia, with the idea of adopting it as a profession. He had

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also a strong inclination for engineering, and some work which he did in 1859 on the line of the Pennsylvania Railroad decided him to enter the service of that Company in March, 1860, as an Assistant Engineer. In 1863 he was appointed Resident Engineer of the Middle Division of that road, and in 1865 Principal Assistant Engineer over the whole road, in special charge of bridges, his title being afterwards changed to Engineer of Bridges and Buildings. He retained that post until 1886, the duties of the department being gradually enlarged and extended until it included all the lines of the Company from New York on the east to Pittsburg and to Erie on the west, and from Canandaigua on the north to Quanti, Va., on the south. He also acted as Engineer of Bridges and Buildings on the Philadelphia, Wilmington and Baltimore Railroad. In 1869, as a reward for ten years' service, he was granted special leave of absence in Europe, it being felt that the engineering knowledge there gained, in connection with a pleasure trip, would be of vast service to the Pennsylvania Railroad Company. Through the solicitation of his father, Mr. W. H. Wilson, then Chief Engineer of that line, Mr. Henry Pettit, Mr. Wilson's assistant, was allowed to accompany him. Returning after six months, in the latter part of the same year, the work was taken hold of with renewed vigour, and the line is now studded with monuments of Mr. Wilson's handiwork.

When the great Philadelphia Centennial Exhibition began to be discussed, Mr. Wilson's attention was early turned to it, and long before the competitive plans were asked for, he visited the locality, made studies, prepared sketches of the buildings, and discussed them with the officers of the commission. When competitive plans were asked for, Mr. Wilson joined Mr. John McArthur, Jun., in the competitions, gaining, with him, one of the premiums. The plan of Messrs. Vaux and Radford having been accepted, however, for the main building, Mr. Wilson abandoned all thought of taking an active part in the Exhibition, and continued his duties with the Railroad Company. Afterwards, at the earnest request of Mr. Henry Pettit, and having been granted permission by the Railroad Company, on a strong appeal from the officers of the Centennial Board of Finance, Mr. Wilson was induced again to take an interest in the buildings of the Exhibition, his peculiar abilities and high reputation in constructive details being specially required. Mr. Henry Pettit and he were elected "Joint Engineers and Architects for the Main Exhibition Building and the Machinery Hall." A total revision of the plans was necessary. The columns, trusses, etc., were modified, towers

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were added, the building enlarged, and all details made. In all of these labours Mr. Wilson took an active part. The Machinery Hall particularly was, in many respects, his special design, the plans being all prepared under his superintendence. The successful completion of these buildings and the admirable way in which they answered all requirements is well known. The Centennial Commission awarded Mr. Wilson and Mr. Pettit joint medals and diplomas for their work.

In January, 1876, in conjunction with his brother, he organized the well-known firm of Wilson Brothers and Company, Civil Engineers and Architects, which firm is still in existence. Mr. Wilson was Chairman of the Board of Expert Engineers on Washington Aqueduct Tunnel and Reservoir, acting under a joint Commission of Congress in 1888–89, and also Chairman of the Board of Expert Engineers to examine and report on the railroad terminal question and station, at Providence, Rhode Island, in 1888. He was one of the expert engineers appointed to examine and report on the condition of the elevated railroads in New York City, and on the designs for the New York and Brooklyn Suspension Bridge approaches. He was Consulting Engineer of the Philadelphia and Reading Railroad Company, and had charge for that Company, as between it and the City of Philadelphia, of all the work on the Pennsylvania Avenue Subway. He was one of the expert engineers to examine and report on the improvement of the water supply of the City of Philadelphia in 1899, the work being now carried out in accordance with that report, and in 1891 he reported on the question of rapid transit to the Railroad Commissioners for the City of New York.

Mr. Wilson was the architect of the original Pennsylvania Railroad Broad Street Station, Philadelphia; his firm were the architects and engineers of the Reading Terminal Station, in Philadelphia, the new station recently finished at Richmond, Virginia, for the Chesapeake and Ohio and the Seaboard Air Line Railroads; the Drexel Building, Philadelphia; the United Gas Improvement Company's offices, in Philadelphia, and numerous other buildings for that Company; the Drexel Institute, the Presbyterian Hospital, the Norristown Lunatic Asylum and the Holmesburg Prison in Philadelphia, and of many other important structures.

Mr. Wilson was also the architect of the Baltimore and Potomac Passenger Station at Washington, D.C., and of various stations on the Pennsylvania Railroad and its branches. The bridges designed and erected by him comprise all the work on the Pennsylvania

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Railroad for many years, up to 1886, when he resigned from the service of the Company, including the Mount Union Bridge,[1] and considerable work on other lines the number being too great to mention specifically.

Mr. Wilson was a frequent contributor to technical literature. He wrote the "Mechanical and Scientific" and the "Historical" articles for the "Illustrated Catalogue of the International Exhibition of 1876"[2]; historical Papers on the International Exhibition of 1876 for *Engineering*[3]; a Paper for the Institution of Civil Engineers[4] on Port Perry Bridge, in 1880; a Paper on "American Permanent Way" for the British Association, which was read at the Montreal Meeting of 1884; a Paper on "Bridge Specifications" for the American Society of Civil Engineers, in 1886; a Paper on "Schools, with Particular Reference to Trades Schools, especially those of France and England," for the Franklin Institute, in 1889–90; a Paper on "The Philadelphia and Reading Terminal Railroad and Station in Philadelphia," for the American Society of Civil Engineers, in 1895; and several articles from time to time for technical journals.

Mr. Wilson was a Member of the American Society of Civil Engineers; a Fellow of the American Institute of Architects; President of the Franklin Institute from 1887 to 1897; President of the Engineers' Club of Philadelphia for the year 1888; a Member of the American Philosophical Society; and a Fellow of the American Association for the Advancement of Science. He received the degree of Master of Arts *honoris causâ* from the University of Pennsylvania in 1877; medals and awards at the International Exhibition of 1876 in Philadelphia for designs of bridges and buildings; and a Telford Premium from the Institution of Civil Engineers for the Paper already referred to.

Mr. Wilson was married in 1869 to Sarah Pettit, daughter of Judge Thomas McKean Pettit, of Philadelphia. He died suddenly in his office in Philadelphia on the 24th November, 1902.

He was elected a Member of the Institution on the 7th March, 1876.

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[1] Minutes of Proceedings Inst. C.E., vol. xxxix. p. 62.
[2] Published by Gebbie and Barrie, Philadelphia.
[3] *Engineering*, 1875–76.
[4] Minutes of Proceedings Inst. C.E., vol. lx. p. 309.

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JOHN STEDDY WINBOLT, second son of the Rev. T. H. Winbolt, was born at Hadley on the 8th March, 1841. He was educated at King's College, London, and in 1860 entered at Trinity College, Cambridge, where he graduated in 1864, being 36th Wrangler of his year, and proceeded to M.A. in 1867. After serving articles to Mr. Peter Barlow, from 1865 to 1867, he obtained, in 1868, the appointment of Government Surveyor at Malacca, which post he held until 1871, when he entered the service of the Japanese Imperial Railways as Inspecting Engineer. He remained in Japan until 1873, when he returned to England in bad health.

In 1874 Mr. Winbolt entered the service of the Great Eastern Railway Company, and for the next six years was engaged as an Assistant to Mr. Alfred Langley, who was then Chief Engineer to that line. In 1881 he was appointed Engineer in charge of the Company's Western Division, with headquarters at Cambridge, first under Mr. Langley and subsequently under Mr. John Wilson, the present Chief Engineer. He retained that responsible post until 1895, when, in consequence of failing health, he was obliged to resign. He died at his residence, 13 Harvey Road, Cambridge, on the 6th January, 1903.

Mr. Winbolt was elected an Associate of the Institution on the 4th May, 1869, was subsequently placed among the Associate Members, and was transferred to the class of Members on the 26th April, 1887.

ARTHUR ERNEST BALDWIN, son of the late Mr. John Baldwin, was born at Warwick on the 1st January, 1854. After being educated at King's College, London, of which he became an Associate, obtaining the Freake Engineering Prize, he served a pupilage of four years under his father, who was at that time engaged as Contractor's Engineer on the construction of the Sharpness Docks on the Severn. On the completion of those works, the subject of this notice was employed on the construction of the Glaston Tunnel on the Kettering and Manton Railway, under the late Mr. W. H. Barlow, Past-President. This was a heavy and important piece of work, claiming continual attention and watchfulness. For some months in 1879 he was engaged as an Assistant Electrician at Messrs. Siemens' works at Charlton during the construction of the French Atlantic cable, and from July of that year he was employed on the construction of the new docks at Milford. His next appointment was that of Contractor's Agent for

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the late firm of Messrs. S. Lake and Taylor, who then took over the dock works. Subsequently he became Consulting Agent and Engineer to the firm, all works in their hands being placed under his direction. He resigned that post to become Engineer to the Milford Haven Railway, and later Manager and Engineer to the Milford Haven Estate and Railway, which appointment he held until his father's death in 1891, when he retired from professional work.

Mr. Baldwin was a good organizer and administrator, far-seeing, and clear-headed, a geologist, and an antiquarian. For twenty-one years he served as Captain, first in the 5th Pembrokeshire Volunteers and subsequently in the Pembrokeshire Artillery Militia, in which latter he held the honorary rank of Major. He died at his residence, Ernesbrake, Southend-on-Sea, on the 26th May, 1902.

He was elected an Associate Member of the Institution on the 6th April, 1880. As a Student he contributed in 1876 a Paper "On Tunnel Construction and on the Sydenham Tunnel, London, Chatham and Dover Railway." [1]

WILLIAM AITKEN DUFF, born on the 30th November, 1859, obtained his first practical engineering experience with Messrs. Robert Ward and Company, railway contractors, and with Messrs. P. and W. Maclellan of the Clutha Ironworks, both Glasgow firms. He then served a pupilage, from 1879 to 1884, to Mr. William Robertson Copland, of Glasgow, on water, drainage, pier and dock works. After being employed in 1884 by Mr. John Strain in the preparation of railway plans and in Parliamentary and field work, he went to Spain, where he assisted in laying out a line of 18 miles in length for Mr. Strain, from Tharsis to the mines of the Tharsis Sulphur and Copper Company at Calañas. Mr. Duff was next engaged on the construction of a section of the Manila Railway, on the completion of which work he went to Hong-Kong to report on petroleum and gold-mining prospects in the island of Timor. Returning to Manila in 1898 he started in business on his own account, being employed on harbour, dock and reclamation work, and remained there during the war between the United States and Spain. Latterly he acted as Consulting Engineer to the Manila Railway until his death, which took place on the 20th March, 1902.

Mr. Duff was elected an Associate Member of the Institution on the 1st December, 1885.

[1] Minutes of Proceedings Inst. C.E., vol. xlix. p. 232.

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THOMAS MONTAGUE HOWDEN, born at Williamstown on the 23rd December, 1865, was a son of the late Mr. Francis Welsh Howden, for many years Secretary for Trade and Customs to the Victorian Government. After matriculating at Melbourne University, the subject of this notice was employed, during the years 1883–85, as a draughtsman in the Victorian Railway Department. Thence he passed, in a similar capacity, into the service of the Water-Supply Department of the same colony. In 1889 he was appointed to the permanent staff as a certificated Engineer of Water-Supply under the Chief Engineer, Mr. Stuart Murray. It was a period of marked activity in the prosecution of water-supply schemes throughout the colony, both for domestic and for stock and irrigation purposes, and Mr. Howden's duties comprised the review of the schemes and the supervision of the works of a large number of town and country bodies expending loan funds under Government control.

In 1898 Mr. Howden was appointed as "Expert Officer" to supervise, on behalf of the Government, the expenditure of about £45,000 in improving and completing the pumping-plants and distributing works of the Mildura Irrigation Colony—a responsible position attended with no little difficulty. With his young wife and family he took up residence at Mildura. By 1901 his labours there were nearing completion when failing health compelled him to seek leave of absence. He was not again to resume duty, and after patiently-borne suffering died at Christmas Hills on the 9th November, 1901.

Mr. Howden's career in the Water-Supply Department had won the approbation of his professional Chief, and the Minister for Water-Supply on learning of his death expressed high appreciation of his ability and good qualities. Possessed of marked ability and tenacity of purpose, careful, methodical and neat in all his work, Mr. Howden's steady progress in professional advancement was to be expected. But it is for his upright, manly and generously kind qualities that he will be chiefly remembered by those who knew him best.

Mr. Howden was elected an Associate Member of the Institution on the 5th May, 1891.

JOHN MACNIE, born at Stirling in 1831, began his engineering career in 1850 as an Assistant to the late Mr. Dow, then Manager of the Gasworks in that town. On the resignation of Mr. Dow in

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1857 he was appointed Manager of the Works, which post he held for seven years. From 1864 to 1867 he was Engineer and Manager of Limerick Gasworks, and in the latter year he was appointed Manager and Secretary to the Londonderry Gaslight Company. He retained those posts until 1899, when failing health obliged him to resign the managership, but he continued to discharge the duties of Secretary until shortly before his death, which took place at his residence, Foyle Bank, Victoria Park, Londonderry, on the 21st October, 1902.

To Mr. Macnie is due a large share of the credit for the successful operations of the Londonderry Gaslight Company. It was mainly owing to his efforts that the Company obtained the Act under which it is now working, and to his foresight was due the necessary extensions of the works. He frequently advised other companies as to improvements and questions of gas production.

Mr. Macnie was elected an Associate of the Institution on the 28th May, 1878, and was subsequently placed in the class of Associate Members.

HENRY JAMES CASTLE, born in London on the 30th November, 1845, was the fourth son of the late Professor Henry James Castle, of King's College, London. After being educated at King's College and at St. Thomas's Hospital (Science), he went to Normandy, and finished at Heidelberg University. He then became an Assistant Engineer on the Boston section of the Great Northern Railway.

In 1865 he went to Spain as an Assistant Engineer on the construction of the Andalusian Railway. Returning to England in 1866 he was employed for some years in his father's office as an Engineering Surveyor and as Assistant Lecturer and Demonstrator at King's College, London.

In 1866 Mr. Castle founded the firm of Castle and Castle, Rating Surveyors, Valuers, Engineers, etc., of which he was the senior partner. He was subsequently engaged by over one hundred Unions in England and Wales, on assessment matters, and successfully conducted many rating appeals at Sessions. His most successful cases were Boden and Co. *v.* Chard Union, and Gifford Fox and Co. *v.* Chard Union, and it was on his advice that the Chard Guardians fought the case in the House of Lords which settled for the time being the question of the rating of machinery. These cases also confirmed the Court of Appeal's decision in the Tyne Boiler Case.

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Mr. Castle was elected a Fellow of the Surveyors' Institution in 1881, and an Arbitrator to the London Chamber of Arbitration in 1893. He died on the 8th February, 1903, at Hampstead, in his fifty-seventh year.

Mr. Castle was elected an Associate of the Institution on the 4th February, 1873.

ABRAM STEVENS HEWITT[1] was born in a log cabin. His father was sent to the States in 1790 by Boulton and Watt, and the mechanic, for such he was, helped to set up the first engine used in America. Abram Hewitt first saw the light of day in 1822, in the then remote little town of Haverstraw, in New York State, where his father had settled and become a cabinet-maker. It was the intention of the elder Hewitt to make his son the master of some trade—and master he became, beyond his father's fondest hopes—but the parent gave way to the boy's desire for book-knowledge.

Abram Hewitt made the most of every advantage offered by the schools near his home. He determined to go to college; but while he was preparing, partly with the help of the master of the district school, and partly with that of the Haverstraw parson, his father lost every cent of his hard-earned savings. Then Abram found out that some good man had endowed a prize for the student who passed the best entrance examination at Columbia. The prize was enough money to pay the tuition-fees through the college. He won the prize, and during his stay at Columbia earned his living by tutoring dull students in classes below him. Still further he increased his income by competing for, and winning, every prize offered for mathematics while he was at the New York College, as well as three prizes for Greek. All through his life he continued to read Latin and Greek. He graduated in 1842. He was endowed with nervous American energy, and worked so hard at school that when he came out his sight was affected and his health impaired. As soon as his condition would permit, he took up the study of law, meanwhile tutoring. In 1843 he was the acting-professor of mathematics at Columbia, and in 1845 he was admitted to the Bar.

In that year the son of Peter Cooper, the great philanthropist, was in the graduating class at Columbia, but because of his delicate physical condition he did not keep up with his class. Peter Cooper

[1] This notice has been reprinted, with certain modifications, from *Engineering*, 6 February, 1903, by permission of the Editors.

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engaged Hewitt to take his son on a tour abroad, and to act thereon as his tutor. Afterwards each of those young men became Mayor of New York.

On the return voyage the two young men were shipwrecked, and spent a day in an open boat on the high seas. This experience, in which Hewitt showed his devotion to his charge and to duty, set a seal on the intimacy of the men; and on their return, when Peter Cooper was about to embark his son in business, Hewitt was asked if he would accept a partnership in the concern. Peter Cooper was then, as he was for years after, in the glue business. He had, however, a small rolling mill near an iron mine he owned in what is now the town of Trenton, New Jersey. The new firm of Cooper, Hewitt and Company was formed of Edward Cooper, Abram S. Hewitt and Peter Cooper. The young men took charge of the works at Trenton, and Mr. Hewitt gave special attention to the making of steel, in which industry he became one of the first experts of the United States. The firm was the first to manufacture iron girders and supports to be used in fireproof buildings and bridges, and was the first to install a Bessemer converter. Its great financial success was based on Abram Hewitt's close study and prescience of the iron market. From 1873 to 1879 the business was conducted at a loss of $100,000 per annum. Then came a great increase in the value of iron, an increase which Mr. Hewitt had foreseen, and which cleared for the firm more than $1,000,000 alone by the increase in the value of the product in hand. More from a philanthropic instinct than from a foresight of the advance in manufactured iron at that time, Mr. Hewitt had kept his mills running at the loss mentioned, storing away the products he could not dispose of. It is a notable fact that although the firm is a large employer of labour, there has never been a strike, even when every other ironworks closed down, at Cooper, Hewitt and Company.

"I hope when the time comes it will be said of me that I was a statesman," said Mr. Hewitt not long before he died. "I care little for political strife except as the good of the community may be effected, or for business successes except as the general welfare is in that way influenced. But on my public papers and endeavours, and on my work and speeches in Congress, I hope to be judged, and that it may be said that as a statesman I laboured. Do not be misguided by giving too much attention to small personalities. You will find, when you reach my age, that if you have lived up to your best judgment, that is about all that a man can hope to do."

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Of higher importance to the world to-day than all else that Mr. Hewitt gave, perhaps, are his views uniformly expressed in regard to the necessity for the association in great enterprises of capital on the one part, and of labour in the form of unions on the other. Mr. Hewitt, himself, believed that his discussions of this important matter were already bearing fruit in America, and that events would show that he was right in diagnosing the trend of modern progress. This, he declared, would result in the diffusion of ownership accompanied by the concentration of management.

Though Mr. Hewitt had studied law, he never practised it. His first step in public service was in 1867, when he was one of the Paris Exhibition Commissioners. There he wrote a wonderful report on iron and steel, which was printed by the Congress of the United States, and translated into many languages. He was elected to Congress in 1874, and served continuously, except for one term (two years) until 1896, when he defeated Theodore Roosevelt in the campaign for Mayor of New York. In the notable campaign of 1876, when each party claimed to have elected its candidate for President, to Abram S. Hewitt, probably more than any other man, is due the averting of another civil war in the States. Mr. Hewitt served but one term as Mayor of New York, because by his honesty, and the fact that he could not be influenced, he incurred the animosity of the regular democratic party, so-called—the autocratic institution of Tammany Hall. He rather expected the nomination by the Republican party, but he had been too staunch a democrat in national affairs.

Space does not admit of enumeration of all the good and great works of Abram Hewitt. As the acknowledged father of the underground transit system of New York, the first links of which are just nearing completion, he is entitled to the deepest gratitude of his fellow-citizens.

In his own estimation the most successful feature of his career was the organization of the Cooper Institute. In youth he had realized the hardships the boy without means experiences in attempting to get a technical education. There was not a place in New York—or in all America for that matter—where this could be had free, and every boy who desired knowledge could not win a scholarship that would pay his way through college. Mr. Hewitt brought the plan of a free technical college before Peter Cooper, who gave a vast building and 100,000 dollars as a nucleus for the institute, and made him president of the six trustees. The Hewitt family and the Coopers have given hundreds of thousands of dollars for many years to the fund; Mr. Andrew Carnegie has

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given, all told, 600,000 dollars, and donations of large amounts have been received from other philanthropists, so that now the establishment is able to educate in higher sciences over 3,000 pupils, who otherwise would probably go no farther than the public high schools.

Mr. Hewitt was elected President of the American Institute of Mining Engineers in 1876, and again in 1890. In the latter year the Bessemer gold medal was awarded him by the Iron and Steel Institute. On his eightieth birthday, last summer, Mr. Andrew Carnegie cabled to him from Scotland, "Cordial greetings on ten octaves, every note truly struck and grandly sung." President Roosevelt wired: "Hearty congratulations on your eightieth birthday, and congratulations to New York for having in you one of the best possible object-lessons in good citizenship."

The business offices of Cooper, Hewitt & Co. have long been at 17 Burlington Slip, where Peter Cooper's glue offices were. Here, in an old-fashioned room, with furnishings of forty years ago, Mr. Hewitt directed his large business interests. He was a director of the following concerns:—The Alabama Consolidated Coal and Iron Company; the American Bridge Company; the Chrysolite Silver Mining Company; the Erie Railroad Company; the Lehigh Coal and Navigation Company; the New Jersey and New York Railroad Company; the New York, Susquehanna and Western Railroad Company; the Northern Railroad of New Jersey; the Shelby Iron Company; the United States Steel Corporation; and several banking institutions.

He was married in 1855 to Sarah A. Cooper, the only daughter of Peter Cooper, and was the father of six children, of whom Peter Cooper Hewitt, the eldest son, is the discoverer of the Hewitt electric light and static converter.

Mr. Hewitt was elected an Associate of the Institution on the 7th December, 1869.

GEORGE BRAITHWAITE LLOYD was born in October 1824, and obtained his preliminary engineering training at marine boiler works at Liverpool, and at the Shildon Works of the Stockton and Darlington Railway, now part of the North Eastern system. He afterwards became a manufacturer of wrought-iron boiler tubes in Birmingham, but in a few years, on the death of his father, he succeeded to a partnership in Lloyds' Bank, which became a limited company in 1865, and formed the nucleus of the

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present Lloyds' Bank. He was a Director of the Midland Railway from December, 1865, to April, 1876, and took great interest in locomotive and other engineering questions, serving on the Locomotive, Stores, and Way and Works Committees.

In November, 1870, Mr. Lloyd became Mayor of Birmingham, and though remaining a Director of Lloyds' Bank to his death, the greater portion of his time was devoted from that date to public work. He was Chairman of the Lunatic Asylum Committee for nearly thirty years, and also took active interest in the Birmingham General Hospital. Mr. Lloyd died at his residence, Edgbaston Grove, Birmingham, on the 8th February, 1903, leaving one son, Mr. John Henry Lloyd, a director of the tube works of Lloyd & Lloyd, Limited, now Stewarts & Lloyds, Limited, who was Lord Mayor of Birmingham for the year 1901–02, his father still being an Alderman and a member of the City Council.

Mr. Lloyd was elected an Associate of the Institution on the 2nd May, 1876.

*** The following deaths have also been made known since the 28th February, 1903:—

Members.

BELL, HORACE; *died* 10 April, 1903.

BOTHAMS, JOHN CHAMPNEY; *died* 14 March, 1903.

BREBNER, ALEXANDER; *died* 15 April, 1903.

CHAMBERS, JOHN; *died* 20 February, 1903.

DOWNEY, ALFRED CHRISTIAN; *died* 19 April, 1903.

GREENE, WILLIAM HENRY; *died* 1902.

HENDERSON, JAMES; *died* 13 April, 1903.

MONBO, THOMAS; *died* 1902.

SHERVINTON, THOMAS ROBERT; *died* 30 April, 1903.

STRONG, EDWARD GRAY; *died* 23 April, 1903.

Associate Members.

MARCET, ALEXANDER; *died* 21 March, 1903.

PETREE, MARSHALL; *died* 13 April, 1903.

SANFTLEBEN, DANIEL ADOLPHUS PLENGER; *died* 1903.

SAYER, SAMUEL; *died* February, 1903.

Associate.

SPEIGHT, RICHARD; *died* 19 September, 1901.

Information as to the career and characteristics of the above is solicited in aid of the preparation of Obituary Notices.—SEC. INST. C.E., 15 May, 1903.

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Sect. III.

ABSTRACTS OF PAPERS IN SCIENTIFIC TRANSACTIONS AND PERIODICALS.

The Bex-Gryon-Villars, and Aigle-Leysin Mountain Railways, Switzerland. K. A. Breüer.

(Schweizerische Bauzeitung, vol. xxxix., 1902, pp. 275, 285, etc. Figs.)

The Author describes two electrically worked mountain railways on the Abt system, which have been recently opened for traffic in Switzerland, one known as the Bex-Gryon-Villars line, and the other as the Aigle-Leysin line.

The first line connects the station of Bex on the Jura-Simplon line with the health resorts Gryon and Villars, the second connects Leysin, a place only second to Davos, with the Rhone valley. An altitude of 3,180 feet can now be attained in 50 minutes, whereas a drive of 3 to 4 hours was formerly necessary. Both lines are of very similar character, being of metre gauge; the Bex line has a maximum gradient of 6 per cent. upon the adhesion portion of the route, and 20 per cent. upon the rack portion, with a minimum radius on curves of 98·4 feet, while the similar figures for the Aigle line are 9 per cent., 23 per cent., and 82 feet. The Bex line is 7·75 miles long, and its course is shown upon a map in the original.

The power is developed in a hydro-electric generating-station, and the Author describes the various railway stations upon the route.

The principal construction upon the line is a cantilever lattice bridge, 466 feet long and 164 feet high, spanning the gorge of the Gryonne; this was built in Vevey. Direct current at 650 volts is used without any transforming devices.

The Aigle-Leysin line is also shown upon a map, and its course described in detail. Electricity is generated at Vuargny by the falls of "Grande-Eau," and is delivered to a sub-station at 2,000 volts and 50 amperes; it is there transformed by rotary machines to 600 volts and 135 amperes. A Pollak secondary battery of 285 cells and 840 ampere-hours capacity is in use, and will give a discharge of 280 amperes, and a booster is used for charging.

The current is carried by bare overhead wires and supplied to the trains by means of trolleys. The electric locomotives were built at the Winterthur locomotive works, and each weighs 15

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tons. Diagrams of the electric connections are given in the original.

The total cost, including the transformer-station and rolling-stock, was, for the Bex line £56,000, for the Aigle line £72,000.

E. R. D.

Fall of the roof of the Cornallaz Tunnel at Chexbres (Switzerland).

(Schweizerische Bauzeitung, vol. xl., 1902, p. 84. 2 Figs.)

The tunnel of Cornallaz is 540 yards long, and situated between the stations of Grandvaux and Chexbres upon the Lausanne-Berne line, and runs through one of the spurs of the Lavaux mountains. On the Grandvaux side it passes through gravel, and on the 2nd May, 1902, some workmen perceived that the woodwork of a drainage aperture was giving way. They immediately left, and the roof suddenly gave way, and large blocks of rock fell through the opening. The entire tunnel is lined with masonry. Falls continued for some days, and as soon as an inspection could be made it appeared that the roof had fallen for a distance of 35 feet. Specialists were consulted, and finally the Jura-Simplon Railway Company decided to place the work of repair in the hands of Messrs. Fougerolle Bros., who have had great experience in similar cases. The Author describes the damage, and states that the fall was caused by heavy rains, which had washed the earth out of the ground directly over that part of the tunnel, leaving the loose rocks resting directly upon the arch.

The methods of temporarily timbering the roof and the large opening above it are shown by cuts in the original, and after the masonry had been made good, the arch was covered with cement, then with iron plates treated with pitch, and, above these, dry masonry was put in to permit of drainage, and ample channels left in the masonry for that purpose also. The cavity above the dry masonry was finally filled with coke-breeze concrete. Traffic was entirely stopped for 53 days.

E. R. D.

The Gellivare Northern Railway.

(Teknisk Tidskrift, 1902, p. 429.)

This, the northernmost railway in the world, was opened for traffic at the end of November, 1902. It connects Gellivare with the port of Narvik on Ofoten Sound in Norway, the principal object being to furnish an outlet on the Atlantic side for the produce of the Kirunavare and Lussovare Iron Ore Mines; the export from

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Gellivare being confined to the port of Lulea on the Gulf of Bothnia. The total length of the line is about 270 kilometres, divided into a southern section of 160 kilometres, a northern section to the Swedish frontier of 70 kilometres and 40 kilometres on the Norwegian side. The work, which has been carried out by the Swedish Government, was commenced in 1898 from both ends simultaneously, the ground being divided into 35 districts—5 in the northern and thirty in the southern section—with a divisional engineer in charge of each one. The chief difficulties encountered were due to the barren nature of the country and the extremely rigorous climate. In the northern section the ground is frozen for ten months in the year, and, in places, all the year round, and the snowfall varies from 12 to 14 metres in depth. In some of the heavy rock cuttings in the mountain sections the work was carried on in winter by tunnelling through the snow, the roof of the tunnel being secured by regular masonry in hard frozen snow blocks. The working force varied with the time of the year, being at the lowest (300 to 500) in December, and at the highest (2,200 to 2,900) in July. The ordinary working season was from June till September. From Gellivare to the east end of Tornea Träsk, the lake at the head of the Tornea River, the country traversed is a barren moorland almost devoid of vegetation, but presenting no very special difficulties, the maximum gradient being about 1 in 100, the most important work being the bridges over the Kaitum and Kalix rivers, the former having three parabolic-headed lattice truss spans of 27 metres each, and the latter one of 60 metres span.

From the lake the line follows a wild mountain country reaching the summit at the frontier at a height of 520 metres in a tunnel 900 metres long, which is not only the longest on the line but also the longest in the whole of Sweden. On the Norwegian side the works are very heavy, the gradients rising to 1 in 60, and there are 17 tunnels, of a total length of 3,973 metres in 25 miles. The most important bridge on the line is over the Norddal. This is 162 metres long and 60 metres above the level of the river, with tunnels of 290 metres and 570 metres long on either side. The line terminates at Narvik, where a new town is rapidly growing up.

H. B.

Locomotives and Rolling Stock on the Eastern Railway of France. L. Salomon.

(Mémoires de la Société des Ingénieurs Civils de France, 1902, p. 523.)

Connected from 1870 with the Eastern Railway, for the last sixteen years as chief mechanical engineer, the Author devoted his inaugural address, as President of the French Society of Civil Engineers, to the increase which has taken place during the past thirty-two years in the traffic of that railway. From his

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compilation of data for 1870 and for 1902, the chief of those furnished for the latter year show the present position of the locomotive, carriage, and wagon department. From 2,837 km (1,763 miles) in 1870, the mileage has risen to 4,862 km (3,021 miles), which is now worked by 1,380 locomotives. There are still 26 single-driving on Crampton's plan; 416 with four wheels coupled, including 20 tank-engines; 670 with six wheels coupled, including 130 tank-engines; 188 with eight wheels coupled; and 80 tank-engines in station-yards. Of the four-wheel and six-wheel coupled engines, 108 are compounds with four cylinders, and 16 kg (230 lbs. per square inch) working pressure; their grate area is 2·52 m² (27 square feet), heating surface 207 m² (2,230 square feet), load on driving axles over 17 tons, and total weight in running order 65½ tons. None of the present boilers carry less than 8 kg (115 lbs. per square inch) working pressure. The total hauling power of the locomotive department has been increased about 95 per cent. since 1870, while the increase in the number of engines has been only 58 per cent. The 130 tank-engines with six wheels coupled are some of the most powerful now working on French lines; originally designed in 1880 for the Vincennes and suburban traffic, they have answered well; they have a trailing axle not coupled, weigh 57½ tons in running order, and can take a train of 22 two-storey carriages, seating 1,760 passengers. For enabling them to take through-trains at 90 km (56 miles an hour) without injury to permanent way, fifty were altered in 1898–9 by substituting a bogie for the leading coupled axle, and coupling the trailing axle instead. The Crampton design, introduced in 1849, and well worked out by Cail, presents so many practical advantages that it has held its own ever since, despite the solitary drawback of its adhesion-weight being limited to 10 tons, owing to the position of the single driving axle behind the fire-box. In 1870 these engines were still taking the Strasburg express, the fastest train of that period, doing the run of 502 km (312 miles) in ten hours and ten minutes; the weight of the train was from 80 to 100 tons; and the running speed, exclusive of stoppages, averaged 57·6 km (35¾ miles an hour). For increasing the tractive power, while preserving the general Crampton arrangement, the pair of carrying wheels in front of the fire-box were coupled to the driving wheels behind it; the adhesion-weight was increased to 13·7 tons, and the boiler pressure to 9 kg (128 lbs. per square inch). On this plan 62 engines were built from 1877 to 1885; they are still in use, after running more than 68 million km (42,250,000 miles) in the aggregate. Owing to the leading axle being allowed lateral play under its load of nearly 15 tons, they have never injured the steel rails of 30 kg (60 lbs. per yard) with which the greater part of the road is laid, though a speed is often attained of 120 km (75 miles an hour).

Compound four-cylinder engines with four wheels coupled were introduced in 1898: working pressure 16 kg (230 lbs. per square inch), grate area 2·52 m² (27·13 square feet), total heating surface

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188 m² (2,024 square feet), adhesion-weight 34 tons, total weight in running order 58 tons. Compared with the Strasburg express of 1870, these engines would now do the same 502 km (312 miles) in seven hours, with trains of 240 tons: showing an increase of 30 per cent. in speed and 140 per cent. in load, which together represent nearly 3½ times the power of the Crampton engines. And while the earlier single-driving single-expansion engines burnt 9 kg per train-km (32 lbs. per train-mile) of coke, the four-coupled four-cylinder compounds are burning only 10·6 kg (37½ lbs. per train-mile) of slack with a little through-coal and briquettes. In anticipation of still heavier trains, compound four-cylinder engines are now being built with six coupled wheels of 2·09 m (6 feet 10¼ inches) diameter; fire-grate area nearly 3 m² (32 square feet), total heating surface 224 m² (2,411 square feet); total weight in working order about 72 tons, adhesion-weight 51 tons. In this way it is hoped to get at least 20 per cent. greater hauling power without the wheels slipping. Of the present four-cylinder compounds with six wheels coupled and bogie, twenty have cylindrical slide-valves,[1] which, besides being balanced, afford larger ports, enabling the engines to run more freely, and with driving wheels only 1·8 m (5 feet 10¾ inches) diameter to maintain easily a speed of 100 km (63 miles an hour). Owing to their nearly uniform driving power throughout a revolution, they can take equally heavy goods trains more easily with their adhesion-weight of only 49 tons than can the eight-wheel-coupled engines with 52 tons adhesion-weight.

The passenger carriages now number 3,685, of which 269 have through communication more or less complete, and 565 are in two storeys; all run on four wheels, some with a wheel-base as long as 7·5 m (24 feet 7 inches). A large number are now heated by a mixture of steam and compressed-air, whereby a train of 24 carriages is warmed throughout its entire length, while barely half this number can be warmed by steam alone; the air carries along with it to the tail end of the train both the steam and the condensed water. All express trains are fitted with the Westinghouse automatic brake. The carriage body is separate from its underframe, on which it is supported at four points by laminated springs, whereby the running is rendered as smooth, and as free from tremor and noise, as that of bogie carriages. A first-class carriage weighs upwards of 17 tons empty, or 710 kg (0·7 ton) per passenger, and costs 32,000 f (£1,280). Luggage vans, horse-boxes, etc., for express trains number 1,551, and run up to 13 tons.

The 31,800 goods wagons now in use carry from 5 to 30 tons load. All are four-wheeled, except the 30-ton wagons, which are on bogies. The capacity of the covered wagons is 30 m³ (1,060 cubic feet), and of the open high-sided 24 m³ (850 cubic feet). All have lever-brakes on one axle. Large American

[1] Minutes of Proceedings Inst. C.E., 1902, vol. cli. p. 451.

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wagons to carry 35 to 50 tons would be unsuitable for French railways, on which the loads per wagon average only 5 tons. Recently mineral and coal-wagons have been built to carry 20 tons with only 7·8 tons tare.

The principal improvements in the construction of engines and tenders since 1870 have consisted in the substitution of steel in place of iron for axles, tires, and boilers; of cast-steel for wheel-centres and axle-boxes; and of white-metal washers for packing piston-rods and valve-rods. The rolling-stock now has steel axles and tires; the latter are secured on the wheel-centres by a continuous lip or fillet, which, being shaped by special machinery, renders this mode of fixing no more expensive than the old plan with bolts and rivets, while it is also much safer. White-metal bearings made with tin, instead of bronze, and mineral oil instead of colza, have been attended with greatly diminished trouble from heating, and with 12½ times less cost of lubrication, whereby a saving of half-a-million francs (£20,000) per annum has been realized. Two-thirds of the present rolling-stock have steel underframes. Drawbars and drawhooks are made strong enough to stand a pull of 40 tons. Passenger carriages have separate buffing and draw springs; in goods wagons both are replaced by a single laminated spring, having an initial compression of 1,647 kg (1⅝ ton). Minor improvements comprise rolled instead of flat ends for laminated bearing springs; iron or steel bars of suitable sections for the skeleton of the body in open high-sided goods wagons; sheet-iron panels for the bodies of passenger carriages; and varnished paints.

A. B.

New Passenger-Carriages. C. P. Schäfer.

(Organ für die Fortschritte des Eisenbahnwesens, 1902, p. 4.)

Three new types of carriages have recently been introduced on the Bavarian State Railways. These are 4-wheeled bogie corridor carriages of first, second and third class; second and third class; and first and second class. The greatest length between buffers is 18·79 metres (61·66 feet), and the others only vary a few inches from this. The external width is 3 metres (9 feet 10 inches). In making up trains with these carriages the relative proportions of first, second and third class accommodation can be varied as follows: 1 : 3·75 : 3·33; 1 : 2·5 : 5·33; 1 : 2·33 : 1·8. It becomes a question with heavy traffic whether it is not better to use carriages of one class only, so as to avoid passengers of different classes using the same corridor, and to enable passengers to find seats with ease and quickness. The underframes are of timber, the main longitudinals being of pitch pine in one piece each, strengthened with iron tie rods. The framework of the bodies is of air-dried oak. The floors are of pine, and the space between the

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floor and the lining on the underside of the beams is filled with cocoa-nut fibre. Some of the carriages are made with clerestory roof, others have the roof of elliptical arch form. All door frames are of teak. The exposed woodwork in the insides of the carriages is of polished walnut. The second class compartments have arms dividing up the seats, while the first class compartments have no arms to the seats, but are arranged so that they can be converted into sleeping berths with two beds, one above the other. The carriages are lighted with gas, heated by steam, and the ventilation is effected by torpedoes. The first and second class carriage has accommodation for 8 first and 27 second class passengers, weighs 34¾ tons, and cost 40,932 marks (£2,046); the second and third class accommodates 18 second and 40 third class passengers, weighs 32¾ tons, and cost 32,429 marks (£1,621); while the third carriage has seats for 4 first class, 18 second class and 32 third class passengers, weighs 32 tons and cost 33,518 marks (£1,676).

J. G.

Treadles for Single-line Railway.

(Organ für die Fortschritte des Eisenbahnwesens, 1902, p. 243.)

On single lines of railway and in other circumstances the necessity may arise for treadles being actuated only when the train travels in one direction. This paper describes and gives drawings of the arrangement brought out by a German firm of signal engineers to effect this object. The ordinary circuit-closing treadle is placed at the desired point, the circuit from it not being, however, carried direct to the cabin, but through another treadle some distance away, on the side opposite to that from which the train approaches. This second treadle is of such a construction that the wheel passing over it breaks the circuit, but only temporarily. This action is obtained by means of a piston moving in a cylinder normally filled with air. The piston is made, by the action of the wheel, to lift a valve and force the air out of the cylinder. When the wheels have passed, the weight of the piston tends to bring it down, but it only descends slowly, as the air enters the cylinder through a small opening, the amount of the opening, and consequently the rapidity with which the piston returns to its normal position, being regulated by a cock. It is evident that if the wheel of a vehicle passes over this special treadle first, the ordinary treadle will not be actuated, whereas, with the train travelling in the other direction, the electric current brought into action by the wheel passing over the ordinary type treadle will have done its work before the circuit is broken by the wheel passing over the second treadle.

J. G.

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Economical Speed of Goods Trains. R. Gostkowski.

(Organ für die Fortschritte des Eisenbahnwesens, 1902, p. 50.)

It has been proposed to calculate the best speed for goods trains on the basis that the product of the weight of the train of wagons into the speed shall be a maximum. Formulas derived from this principle involve the necessity of concluding that on gradients up hill the speed should be greater than on the level. This appears improbable to the Author, and he proposes to set out from a different principle, namely, that the useful work done by the locomotive shall be a maximum. Putting a, b and r for certain constants to be derived from experiments, c for the speed of the train in metres per second, and L for the weight of the locomotive in tons, the most economical speed is to be derived from the following formula:—

$$2(a + 3bc^2)\sqrt{c}\,L = r.$$

This equation indicates that the most favourable speed is less on an up grade than on the level, which is more in accordance with what the Author would expect. As an example, taking $L=70$, $r=11067$, putting $a=3+m$ where m is the rise of the gradient per thousand, and $b=\frac{1}{70}$, the most economical speed on the level is calculated at 68 kilometres (42¼ miles) per hour. On an incline of 1 in 100 the best speed is given by the above formula at 50 kilometres (31 miles) per hour. The corresponding speeds, as given by the formula first referred to, are 26·7 kilometres and 34·8 kilometres (16½ miles and 21½ miles) per hour.

Although the Author thinks his formula is preferable to any others at present known, he expresses the conviction that in determining the most favourable speed, consideration should be given to the length of the distance to be run by the train.

J. G.

Tests of Locomotive Performance. Von Borries.

(Organ für die Fortschritte des Eisenbahnwesens, 1902, p. 11.)

The tests were those carried out with a four-cylinder compound engine. After previously reported trials certain alterations had been made; the blast-pipe was carried higher and the breadth of the centre rib increased, the inside lap of the low-pressure valves was also increased. As a consequence of these alterations, the power of the locomotive had been augmented so that the useful work obtained from 1 lb. of coal was increased by 17 per cent. The length of the run on each trial was about 126 kilometres (78¾ miles) and on one occasion, with a favourable wind, this was traversed at an average speed of 99 kilometres per hour (62 miles

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per hour). The weight of the train on this occasion was 238 tons, and the calculated power developed 1000 HP.

The average results of six runs are given in detail by the author. The average speed attained was 92 kilometres (57½ miles) per hour. The weight of locomotive and tender was 87 tons, and of the train of coaches 276 tons. The tractive force for locomotive and tender was 1·2 tons, and for the train 1·5 tons, total 2¾ tons. The average performance for engine and tender and train was 928 HP. The power developed per kilogram of coal burned per hour was 1·04 HP. (2·1 lbs. per HP. per hour). The power developed was equal to 10 HP. per ton weight of locomotive, tender excluded.

J. G.

Lubrication with Graphite for Locomotives. BRUCK.

(Glasers Annalen für Gewerbe und Bauwesen, 15 February, 1903, p. 75.)

The addition of graphite to lubricating oil has been practised for many years, though it has latterly fallen into comparative disuse. Owing, however, to the introduction of a new variety of graphite, known as "flake graphite" (*Flocken-Graphit*), which possesses certain distinct advantages over the material formerly employed, this admixture has again come into favour. The Author describes some trials made with this lubricant. The method of using the mixture, by saturating cotton waste with a compound of mineral oil, graphite, and a little tallow, which was rammed into the axle-boxes, is explained, the oil being introduced on the upper surface and passed down to the axles through only one of the tubes. In some cases the mixture of oil and graphite was placed to the extent of a few drops daily on the actual bearing surface; in others a very thin compound of oil and graphite was permitted to flow through the wicks, or to drip from the lubricators. The proportion of the graphite to the oil actually used during a running trial of 5,592 miles was approximately as 1 to 800 by weight. The saving in oil was about 50 per cent., and the number of hot bearings was greatly reduced. The action of the graphite seems to be that it prevents the escape of the thin fluid oil from the bearing-surfaces, and at the same time it decreases the pressure on the bearings, as it tends to act in the same way as a denser lubricating material would do without its disadvantages. The flakes of which it is composed tend to insert themselves, moreover, into the small inequalities in the metal of the bearings and give a completely smooth running surface.

G. R. R.

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Electric-Accumulator Traction on Heavy Railways. MÜHLMANN.

(Organ für die Fortschritte des Eisenbahnwesens, 1902, p. 133.)

On the Wurtemburg State Railways trials have been made in the running of Serpollet steam motor-cars and Daimler benzine cars for local traffic. A car driven by electricity derived from accumulators has also been run, and the experience obtained with it is detailed in this paper. As the passenger traffic on a certain line about to be opened was expected to be light, it was considered desirable to utilize motor carriages instead of the usual steam trains, and the offer of a firm of manufacturers to fit up a carriage with electric motors and accumulators at their own expense was accepted. The carriage, supported on two bogies, was 11·6 metres (38 feet) in length, and had the batteries, which weighed 6·4 tons, under the floor in the centre of the car. The discharge voltage of the cells was about 360, the current varying from 36 to 228 amperes. The lines over which the carriage was run had a good deal of 1 in 100 gradient. After running 9,890 kilometres (6,142 miles) the battery was entirely done, and complete renewal became necessary. The average work expended was 2,050 watt-hours per kilometre (4·4 HP.-hours per mile). Another accumulator was put in by the same firm, and the carriage was run on a different route, but one having still numerous grades of 1 in 100. The total number of kilometres run with the new batteries before they were completely used up was about the same as before, but the average work per kilometre was about 25 per cent. less. The comparative failure of these two trials was attributed to the steep gradients. Another firm then fitted up the carriage with accumulators of their own make, and the route selected for the further trials was chosen for its comparatively easy gradients. In this case the carriage ran a total of over 11,000 kilometres (6,831 miles), the average output per kilometre being 885 watt-hours (1·9 HP.-hour per mile).

In further trials a carriage was fitted up with batteries under the seats, the total weight of the cells being 8·65 tons. The seating capacity of the carriage was 64 passengers, and the total weight of the carriage with this number of passengers was 33 tons. The ruling gradient of the route run by this carriage was 1 in 200. The batteries were in regular service for about a year, and in this time 40,439 kilometres (25,110 miles) were traversed, the average expenditure of work being 1,185 watt-hours per kilometre (2·55 HP.-hours per mile). This last series of experiments is dealt with at considerable length by the author, who also gives the results of some special trial trips.

As to the general usefulness of accumulator traction, the conclusion from the series of trials is that it is not suited for lines with heavy gradients, or where there are big rushes of traffic, as on suburban lines. J. G.

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Lock-and-Block Signalling with no Releasing-Key.

O. WALZEL.

(Organ für die Fortschritte des Eisenbahnwesens, 1902, p. 74.)

Several Austrian railways make use of the insulated rail in the working of the block system. When once the signal has been set to clear it can only be put to danger and line clear given to the box in the rear, when the last vehicle has passed the foot of the post. If a train happens to pass the signal at danger, line clear can only be given to the post in the rear by the signalman using a key. This is very objectionable, and, in order to obviate the necessity for using a key, a method has recently been worked out by the Author, although it has no pretensions to being a final solution of the problem. Assume three boxes A, B and C, and suppose that while block B C was occupied by a train No. 1, another train No. 2 passed the home signal at B, necessarily at danger. This prevents the signalman at B using the ordinary methods for accepting a train from A. By the new method it is arranged that a train passing B's home signal at danger connects A with C on the block circuit. When No. 1 train passes out of section B C, the signalman at C plunges to give line clear to A, and at the same time puts B's block instrument in its normal condition. With this arrangement it is absolutely essential that whenever a train passes any post at danger, the block section it has left shall not be occupied until the instruments have been restored to working order.

The Author gives diagrams indicating the details of the system.

J. G.

Point-lock with Electric Release. J. SCHNATTER.

(Organ für die Fortschritte des Eisenbahnwesens, 1902, p. 181.)

The arrangement described is intended for use at outlying sidings and in other similar circumstances. After the points have been moved by hand with the ordinary ground lever, they can be locked electrically by the man on the spot. This locking is repeated electrically in the cabin, the position of the points—normal or reversed—being also indicated. The releasing is effected from the signal cabin by turning the handle of a small magneto-electric machine producing alternating current. At the points, the stretcher bar is prolonged through a slot in the side of a cast-iron box placed just outside the four footway, and slides over the cast-iron bottom of this box. There are two holes in the stretcher bar, and the place of the ordinary plunger is taken by a vertical locking bolt inside the above-mentioned box. This bolt is

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attached to one end of a bent lever, to the other end of which is connected a rod movable vertically in slides fastened to the back of the box. When this rod is lifted up by the man at the points, it locks the points, and also becomes itself automatically locked, by the closing of an electric circuit through which the current from a battery in the cabin passes and energises an electro-magnet with a polarised armature.

The author gives drawings of the box and contained apparatus, and also describes, with diagrams, the arrangements required on the ground at the points, and also in the cabin, for thus controlling the points connecting two loops with a single line.

J. G.

Rolling Platforms for Extension of Wayside Stations.

L. DE NYS.

(Revue Générale des Chemins de Fer, December, 1902, p. 341.)

The Author states that on account of the continually increasing length of trains the platforms at many intermediate stations of the Belgian State Railway have had to be lengthened from 137 yards to about 218 yards. Where the station adjoins a level crossing considerable expense would be incurred by the probable re-arrangement of the goods yard and re-building of the warehouse, and in order to overcome this difficulty a rolling platform locked with the rolling level-crossing gates has been installed which renders the extension of the platform on the other side of the level crossing a comparatively easy and economical matter.

The Author describes in detail the Beernem station where this method has been adopted. He estimated the cost of the preliminary works to enable the platform to be lengthened by altering the line of way leading into the goods yard and re-building the goods shed at £260, but to avoid this a short rolling platform across the level crossing was erected which cost only £27 complete, including the arrangement for the rolling portion to slide under the fixed platform, the rolling portion itself costing £19 12*s*.

The rolling platform is 20 feet long, 6 feet 6 inches in width, and is composed of a steel framework consisting of two longitudinal bearers with $\frac{7}{32}$ inch web, $9\frac{7}{8}$ inches deep, with four angle-bars 2 inches by 2 inches by $\frac{7}{32}$ inch, tied together by five cross-bearers with stringers; the floor of the platform is of oak $1\frac{1}{4}$ inches thick. Four wheels of $10\frac{5}{8}$ inches diameter are fixed to the interior of the frame and roll on rails laid in the paving.

The platform has been in existence since May, 1901, and has given excellent results. A plan of the station and details of the carriage are given in the text.

J. A. T.

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The Bremgarten-Dietikon Electric Street-Railway.

(Schweizerische Bauzeitung, vol. xl., 1902, p. 199. 12 Figs.)

The street line described in this paper runs from the Obertor in Bremgarten to the station at Dietikon, and is 6·8 miles long, with a gauge of 1 metre, the minimum radius of curves is 98·4 feet. The maximum gradient is 6 per cent. for a distance of 115 yards outside Dietikon, and the average gradient is 3·15 per cent. Details of the roadbed and of the rails are given, but these are not essentially different from the usual practice.

The power-station is in the 'Bruggmühle' the electric lighting station close to the bridge over the river Reuss in Bremgarten. Here two dynamos are connected to the same shaft, and driven by belting from the turbines, either machine can be disconnected by couplings. These were built by the Oerlikon Company, develop 85 HP. at 750 volts, and 470 revolutions per minute, and are of the 4-pole type with slotted armatures. The winding is shunt and also compound and the efficiency 91 per cent. at full load. A secondary battery is used consisting of two half batteries each of 200 cells, and having a capacity of 123 ampere hours with discharge of 123 amperes.

The overhead system with two conductors is used with return through the rails, and the working pressure is 700 volts.

The rolling-stock at present consists of three motor wagons, three passenger tow-cars, which can easily be fitted up as motor-cars, and two open and two closed goods wagons. Each motor wagon and each tow-car carries eighteen passengers seated, and also ten passengers standing.

With 700 volts and a speed of 430 revolutions per minute, each motor developes 35 HP., and a speed of 7·5 to 8 miles per hour is maintained upon a gradient of 5 per cent for a distance of 900 yards.

Details are given regarding dimensions of the motors, and methods of control, and it appears that the entire outlay inclusive of plans, rent of land, construction and working capital was about £30,200. E. R. D.

Lattice-Girder Bridges, with Flexible Connections.

R. BONNIN.

(La Nature, 24 January, 1903, p. 113.)

The Author describes a bridge with a span of 137·79 feet over the River Beuvron, on the railway from St. Aignan to Blois, recently constructed by the Compagnie d'Orléans, designed by Mr. Mesnager on the proposition of Mr. Sabouret, the Chief Engineer of the

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Company. By reference to a photograph and to diagrams of the junctions, it is shown that in lieu of the various parts of the girder being riveted together with rigid joints, the attachment of the intermediate braces and struts to the top and bottom flanges in all cases takes the form of a plain plate of metal, without any angle bars or stiffening pieces. Diagrams are given which indicate the excessive strains to which rigid joints of the ordinary kind used in lattice girders are exposed, owing to the deformation due to loading, and the Author refers to attempts made in America to counteract these strains at the junctions of the bracing by employing articulated joints or sockets giving free play in all directions. However, joints of this kind speedily yield to wear caused by vibration and render such an amount of movement or play possible as to endanger the stability of the bridge. Mr. Mesnager, therefore, conceived the idea of joining the vertical and inclined braces to the main flanges by simple strips of metal, fixed in the same plane as the tie itself and of equal width. These joints allow of considerable movement when placed in the longitudinal direction of the span, and when subjected to tension; but the question arose whether the small and flexible junction-strips would not twist and buckle when under compression as, for instance, in the vertical braces. Actual experiments have proved, however, that if their length does not exceed ten times their thickness, these strips will stand any working stress which could arise in practice. Under severe tests this bridge fully confirmed the accuracy of the theoretical calculations, and two other bridges on the same principle have recently been carried out.

G. R. R.

Staircase with Right and Left Treads.

(Teknisk Tidskrift, Stockholm, August, 1902, p. 319.)

In a space too confined for any but the narrowest and steepest staircase, the consequent inconvenience and danger are obviated by making the treads narrower at one side than at the other, like those of a winding staircase, but reversing them alternately right and left. A photograph is shown of a staircase or step-ladder so constructed in the generator-house at Bjuf. Without increasing the height of the risers, the steepness has here been increased to $1\frac{1}{4}$ in 1, while retaining all the convenience of a staircase having the ordinary slope of 1 in $1\frac{1}{2}$.

A. B.

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Use of Caissons with Compressed Air for Extending River-Piers.

(Revue Générale des Chemins de Fer, February, 1903, p. 127.)

A short description is given of the method employed in extending the piers of bridges over rivers for the widening of the Paris-Lyons-Mediterranean Railway. A movable caisson suspended from an overhead gantry is lowered in juxtaposition to the concrete of the old abutment or pier, grooves being made during its descent in the old concrete for the edges of the caisson. After a suitable foundation is obtained, it is raised about one foot at a time as the masonry proceeds, filling up with concrete the interval between the masonry and the side of the trench, and stopping up the grooves in the old concrete with sacks of cement. The work is carried on in this way until the first set off in the old pier is reached, when it is no longer possible to use the caisson for the connecting portion between the old and new piers; the outer portion of the new pier is then built to water-level and racked back, and the caisson raised. For the next operation a fixed coffer-dam caisson of three sides is used, which embraces the two blocks of masonry to be connected. This caisson, which is made to the shape of the two blocks, is closed at its two ends by the blocks themselves, the joints between the metal and the face of the piers being stopped with clay. The connecting piece between the old and new piers is then built up to just above water-level.

A plate is given illustrating the work at the various stages.

J. A. T.

25-*Ton Floating Crane for the Works of the Port of Ceuta.*

(Revista de Obras Publicas, vol. l. p. 345. Figs.)

A crane has recently been supplied for the works in the Port of Ceuta which has some interesting features. It consists of a barge driven by a screw propeller, and upon the deck of the barge is carried a lofty gantry which projects beyond the bow. Upon this gantry runs a traveller, and the vessel is used chiefly for handling the large blocks of concrete used in the construction of the harbour works. The vessel is of shallow draught and built of steel with wooden deck and fittings; its length between perpendiculars is 82 feet, beam 24·6 feet, depth of hold 6·56 feet; it will carry three blocks of concrete and then the draught forward is 2·95 feet, and aft 3·25 feet.

The crane is worked by steam-power, and the traveller moves forward at the rate of 60 feet per minute; the speed of lifting the blocks is 2·5 feet per minute, both corresponding to about 163 HP. The engine is of the compound condensing type, and develops 25 I.HP., and is capable of moving the barge at a speed of 3 miles per hour under favourable conditions of sea and wind.

E. R. D.

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Heating-value of Superheated Steam. C. Bach.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, p. 729.)

In the code of standard tests for steam boilers and engines as fixed in 1899 by the Society of German Engineers, the calorific value of 1 kilogram of superheated steam is set down as being given by the following formula:—

$$w_1 = 606{\cdot}5 + 0{\cdot}305t_1 + 0{\cdot}48\,(t_1^1 - t_1) \quad . \quad . \quad (1)$$

in which t_1 is the temperature of saturation corresponding to the pressure of the steam and t^1_1 is the temperature of the superheated steam.

In carrying out recently some investigations on the conduction of heat, the Author had occasion to determine the amount of heat that passed through the walls of a copper worm filled successively with saturated and with superheated steam. It was found that, without exception, all the amounts obtained were in excess of the values given by calculation from formula (1), whereas, owing to unavoidable losses through radiation, etc., the actual results obtained should have been less than those given by the formula if it were correct.

On calculating the value of the constants from his experiments, the Author puts forward the following formula as representing more nearly than equation (1), but still only roughly, the calorific value of superheated steam per kilogram—

$$w_1 = 606{\cdot}5 + 0{\cdot}305t_1 + 0{\cdot}6\,(t_1^1 - t_1) \quad . \quad . \quad (2)$$

In the experiments with saturated steam, the quantities of heat calculated from the formula—

$$w_2 = 606{\cdot}5 + 0{\cdot}305t_1$$

were always greater than the actual amounts of heat found to have been transferred to the cooling water.

J. G.

Strength of Cylinder-Supports of Vertical Engines. G. Schwarz.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, p. 724.)

The Author considers first the case of a plain rectangular framework of which the two vertical sides alone are capable of deformation; the base is held fixed in a horizontal position, the cylinders are supported on the top of the framework. The deformations arising from pure tension or compression are unimportant, and it is the bending stress resulting from the horizontal component of the thrust in the connecting-rod which is the principal circum-

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stance considered by the Author. If the air-pump is driven from the connecting-rod by a lever with its central bearing supported on one of the verticals of the frame, the thrusts coming on this bearing will also contribute to the distortion of the framework.

Assuming first that the corners of the framework are absolutely rigid, the Author works out formulas for the various stresses and deflections. He applies his theory to a case in which the height of the frame is 160 centimetres (5 feet 3 inches), the side thrust from the connecting-rod 1,400 kilograms (1·37 ton), and the vertical pressure on the bearing fixed to one of the verticals for the driving of the air pump 2½ tons. The total lateral deflection of the frame work at the top is calculated to amount to 0·337 millimetres (0·013 inch). The Author shows also diagrams for the shearing and bending forces acting on the verticals. One of the conclusions from his calculations is that it is of advantage to have the bearing for the air-pump rocking-lever fixed as low as possible. The Author then varies the conditions as to fixity of the sides of the framework, working out formulas and applying them to examples. It appears from these further investigations that slight differences in the lengths of the legs of the framework may account for considerable stresses and deflections. The Author then studies the case where the legs of the framework are inclined outward, and shows that this is of great advantage in reducing the lateral deflection.

The final case treated in the Paper is that of a fixed vertical engine with only one direction of rotation, and for this a graphical method is applied.

J. G.

High-Speed Pumps. LECUIR.

(Revue de Mécanique, November, 1902, pp. 429, etc.)

Until comparatively recent years piston velocities of 0·40 metre per second (1·3 foot) and 60 revolutions per minute were regarded as limiting speeds for pumps. By careful experimenting with the indicator, and by improved design of the valves, etc., the piston speed has been increased to more than 3 metres per second (10 feet per second) and 300 revolutions per minute. High speeds permit of direct drive and reduced dimensions, so that a smaller volume of water per stroke passes through the cylinders for a given delivery, and the liability to shock is thereby lessened. The first researches and deductions of Prof. Riedler (since confirmed by Prof. Bach) showed (i.) that the amount of throttling due to the size of the valve-seats is far from having the value which theory seemed to indicate, even in the case of valves almost theoretically balanced; (ii.) that the shocks are produced especially at the suction-valve; (iii.) that the shocks due to the valves are less in proportion as the mass of water

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between the valves and the level in the air-vessel is less; (iv.) that the shock varies directly as the weight of the valve. Although in theory the equations of continuity assume that the valves rest upon their seats when the piston is on its dead-centres; practically this is not so, the valve being still off its seat when the piston begins its stroke, and the violence of shock depends on the distance of the valve from its seat, and on the mass of water which takes part in the back stroke. Any attempt to limit the lift by means of stops appears to have the contrary effect to that desired, and it is found better to increase the weight of the valve or to load it by means of springs. The same result may be effected by increasing the number of valves, but for high-pressure pumps this offers disadvantages, in consequence of the increased size of the valve chamber.

That the inertia of the valve contributes appreciably to the shock is confirmed by the fact that a heavy valve gives a more violent blow than a light one loaded by a spring, even though the pressure intensity due to the spring be equal only to the weight of the valve alone.

The Author explains the theory of Müller ("Pumpenventile"), which he considers the key to the proper design of the valves, and deduces what he names the "equation of Westphal," which, expressed in words, states that for continuity of flow in the pump, the volume swept by the piston must be equal to the volume swept by the valve in the same time, together with the volume equivalent to the quantity of water which flows through the cylindrical surface generated by the lift of the valve; from which the maximum lift of the valve may be deduced.

The shock due to the closing of the valve is proportional to the product of the mass of water comprised between the levels in the air suction air-vessel and in the discharge air-vessel, into the square of its velocity, plus the product of the mass of the valve into the square of its velocity at closing. It follows that the pumps should be so arranged that the difference of level referred to is as small as possible, as exemplified in the accompanying illustrations. The Author further deduces that the time of descent of the valve diminishes proportionally to its weight, so that this also should be reduced to its smallest limits, the lift being controlled by means of springs either of steel or rubber.

The Author fully describes and illustrates with dimensioned drawings a differential pump. He further states that the best bronze for the valves is composed of 86 per cent. copper, 12 per cent. zinc, and 2 per cent. tin.

E. H. S.

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The Production of Power by Means of Small Motors.

F. DE BOOR.

(Schweizerische Bauzeitung, vol. xl. p. 107.)

The Author refers to a paper by Mr. Weissenbach-Griffin which appeared in the Schweizerische Bauzeitung of 12 July, 1902, and contained tables of comparative costs for the production of power by means of illuminating-gas, producer-gas, steam, and electricity. In that Paper it was stated that producer-gas could not profitably be employed unless the normal load upon the motor exceeded 20 HP. The Author complains that in the earlier Paper sufficient data were not given to enable the results to be checked; he has therefore examined the matter again, and has calculated the costs for motors varying in size from 5 to 25 HP. In order to show his methods he gives the calculations for the 15-HP. motors in detail.

1 Illuminating-gas:—The price of gas in Zurich, 1899, is taken, but the precise cost is not stated; the gas-consumption is taken as 19 cubic feet, the cooling-water as 5½ gallons, and the lubricating-oil as 0·17 ounce per HP. hour. Interest on capital at 5 per cent., depreciation, maintenance and attendance are all allowed for, and the cost for a year of 3,000 hours is said to be £197·6, decreasing to £81·6 for a year of 1,000 hours.

For producer-gas the corresponding figures are £113·2 for 3,000 hours, and £65·6 for 1,000 hours.

For electricity the cost varies according to the city: in Berne the corresponding figures are £176·8 for 3,000 hours, and £153·4 for 1,000 hours, but in both Lucerne and Aarau the cost is lower.

A table shows the relative costs of power from motors of 5, 10, 15, 20 and 25 HP. for all the three classes of energy.

The conclusions drawn by the Author are that producer-gas can be economically used in motors of as low as 5 HP., and in most cases it will be found cheaper than power produced by electricity.

The lowest cost in the table is that for the 25-HP. motor using producer-gas, and this when used 3,000 hours per annum works out at ½*d.* per HP. hour.

E. R. D.

Design of Internal-Combustion Motors. HUGO GÜLDNER.

(Zeitschrift des Vereines deutscher Ingenieure, 1903, p. 606.)

From the principles of thermodynamics to the cylinder dimensions for a given development of power may appear a simple step, but, in the Author's opinion, it is in this direction that the present knowledge of thermodynamics is deficient. To attempt to start from the basis of the theoretical diagram requires the

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introduction of an immense number of factors to allow for the difference between the actual and the theoretical diagram. The simplest and surest foundations for the design of gas and oil motors is to start from the weight of air necessary for combustion of the gas.

The Author works out on this basis general formulas for 4-cycle engines for gas and for liquid fuels, and also formulas for the special cases of lighting, power and blast-furnace gas, also for petroleum, benzine and raw spirit.

For gas motors the following formulas give the diameter d and stroke s of the cylinder in metres, also the number n of revolutions per minute.

$$d = \sqrt{\frac{26{\cdot}787\ N_n (1 + L)}{H \eta_m s\, n\, \eta_v}} \quad . \quad . \quad . \quad (1)$$

$$s = \frac{26{\cdot}787\ N_n (1 + L)}{H \eta_m d^2\, n\, \eta_v} \quad . \quad . \quad . \quad . \quad (2)$$

$$n = \frac{26{\cdot}787\ N_n (1 + L)}{H \eta_m d^2\, s\, \eta_v} \quad . \quad . \quad . \quad . \quad (3)$$

In these formulas Nn denotes the effective HP., L is the number of cubic metres of air required for combustion of 1 cubic metre of gas, H is the heating value of the gas per cubic metre expressed in calories, η_m is the economic efficiency, η_v the volumetric efficiency of the suction stroke.

The Author supplies tables of constants designed to facilitate the application of his formulas to various kinds of fuel and different sizes of motor.

J. G.

Gas-Engine Research. Eugen Meyer.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, pp. 945, 996, 1,303, 1,391.)

The Author commences his second report by giving Tables of the principal numerical results obtained from about ninety tests. For each test twenty-five different items are tabulated. Apart from these results the Author had investigation made by Mr. Brooke Sewell as to the composition of the exhaust gases. The detailed processes and methods of this investigation are contained in the Paper; the final conclusions were that with lighting-gas and at full load there was a loss of heat through imperfect combustion of from 3 to 5 per cent., at half load this was increased to 15 per cent. With power-gas the charge was very variable; at ¾ load the loss through imperfect combustion was at least 13 per cent. Accepting the conclusion from these figures that with lighting-gas 10 per cent. more gas escapes without being burned at 6 HP. than at 10 HP. (full load), it follows that the actual amount of heat

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required per I.HP. per hour is 10 per cent. less at 6 HP. (effective) than at 10 HP. (effective).

Decreasing the ratio of compression from 4·98 to 4·59 increased the heat used per I.HP. per hour by 2·5 per cent. in the case of lighting-gas, and 5·3 per cent. for power-gas. Decreasing the ratio again from 4·98 to 3·84 the above percentages become 9·7 and 13·6 respectively. The Author enters into a comparison as to how theory compares with the practical results of thus varying the degree of compression. He calculates on the assumption of adiabatic expansion and compression both for constant and variable specific heats, and finds that the results are in fair accordance with his conclusions from experiment. As to the question how the amount of heat used varies with the kind of gas, the tests indicate that in the application of power-gas a greater quantity of heat by from 11 to 15 per cent. is used than when lighting-gas is employed. Calculation on the basis of the engine being perfect shows that with power-gas the heat required is greater than with lighting-gas by 3·3 per cent. or 5·5 per cent. according as the specific heat of gas is assumed to be constant or variable. This difference falls far short of the 11 per cent. to 15 per cent. mentioned above. The Author then considers the heat given off to the cooling water, and finds that with power-gas this is from 5 per cent. to 12 per cent. less than with lighting-gas. To account, then, for the greater heat used in the case of power-gas, the Author considers the combustion, and comes to the conclusion that the power-gas is less perfectly consumed than the lighting-gas, and that to this is to be put down the greater efficiency of the lighting-gas.

The Author enters into a calculation of the work that would be obtained from the gas with a perfect engine, and, comparing his results with the work indicated by the experimental engine, finds that, on the assumption that the specific heat of the gases varies according to the laws of Mallard and Le Chatelier, the real engine gives as much work within 11 per cent. as that which would be given out by the ideal engine, whereas, if the specific heat is considered to be constant, the experimental engine gives out one-third less work than a perfect machine. The various sources of loss of work in the engine are considered in detail by the Author. With regard to the endeavour of inventors to improve the gas-engine by obviating the transference of heat to the cooling water, the Author shows from his experiments that the work lost through heat passing to the cylinder walls is relatively small, and cannot be altered to any extent by varying the details of construction. The most important points are the degree of compression and the perfection and intimacy of mixture of air and gas. He expresses the opinion that with the engines at present in use, great quantities of gas pass through to the exhaust unconsumed, and this is especially the case with poor gases.

J. G.

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Heat-Balance of Gas-Engines. A. STAUS.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, p. 649.)

In order to obtain an actual measurement of the heat represented by the exhaust gases of the gas-engine, the Author constructed a gas calorimeter by which he was enabled to determine the temperature of the exhaust, as well as the amount of the heat carried off. The principal parts of the apparatus were a large cast-iron cylinder with, inside of it, a smaller cylinder into which the exhaust pipe was carried, a tank for supplying cold water by means of pipes led through the top cover of the large cylinder, and distributing it by means of perforated nozzles, pipes for leading off the heated water and thermometers for measuring the water and gas temperatures. The sum of the indicated work and the heat measured in the cooling water and exhaust gases came to within 81 per cent. of the heating value of the gas. The Author shows that the combustion of cylinder oil was not such as to affect the result.

The following is the heat balance in percentages :—

	Per cent.
Equivalent of the indicated work at 632·3 calories per HP.	16·18
Heat in cooling water	44·44
„ exhaust gases	37·58
Loss by radiation (difference)	1·80
Total . . .	100·00

The Author gives other particulars of his tests and apparatus.

J. G.

Three-cylinder Compound Gas-Engine.

(The Engineer, 12 December, 1902, p. 571.)

This article describes a vertical gas-engine of 100 HP. constructed by Messrs. Clarke, Chapman and Company, of Gateshead. It has two smaller explosion cylinders and one larger expansion cylinder, the crank of the latter being set more than 180° in advance of the others. The distribution valve is of the rotary type and revolves at one-quarter the speed of the engine. This valve has an upper and lower set of ports; the former admit the charge to the two smaller cylinders and the latter conduct the exhaust from these to the central cylinder. The valve is balanced by the duplication of the ports. The two high-pressure cylinders are fired alternately; in the low-pressure cylinder the products of combustion of each in turn are further expanded, and as the pressure in it diminishes below that of the atmosphere the products are sucked out of the explosion cylinders. The governor acts by throttling the charge.

A. W. B.

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On the Phenomena of Combustion in Stationary Alcohol Motors. SOREL.

(Revue de Mécanique, January and February, 1903, pp. 33 *et seq.*)

The Author describes his experiments on alcohol motors exhibited at the international competition in 1902, and his investigations in connection therewith. These were directed principally to the conditions necessary for the perfect vaporization of the volatile combustible used in these explosion motors, or, in other words, the conditions which determine the construction of a successful carburettor.

The Author describes the method of analysis employed, with results, and in Table II. will be found the analyses of the exhaust gases for a great variety of engines, and the quantity of air introduced in each case. All the motors were run either with alcohol carburetted to 50 per cent. with benzine, or with standard adulterated alcohol. Although samples of each type were perfectly comparable, very different effects on the valves were observed (Table I.), and the analyses of the exhaust gases showed very considerable differences in the efficient utilization of the combustible. It appears from the results that the so-called light motors, weighing less than 30 kilograms (66 lbs.) per HP., have the least efficiency; also that, in exceptional cases, complete combustion may be obtained with not more than 1·3 times the amount of air theoretically necessary; but to obtain a satisfactory combustion continuously 1·5 to 1·7 times the theoretical quantity must be supplied. Bad condition of the valves and bad economy go together, but it does not necessarily follow that the amount of acid in the products is due to the acidity of the alcohol employed, but is more probably due to the formation of acid during the incomplete combustion of the explosive mixture. The great differences observed in various motors the Author concludes must be due to the more or less perfect manner in which the carburation is effected. To obtain the best results, the explosive mixture must be as homogeneous as possible, and drops of liquid must be prevented from adhering to the metallic surfaces and undergoing decomposition either before or during their presence in the cylinder. The primary condition of a good carburettor is therefore, the absolute vaporization of the combustible, and its maintenance in a state of vapour up to the moment that combustion is complete. In consequence, the Author next directs his experiments to the determination of the tension of the vapour of each of the combustibles as a function of their temperature. The method of procedure is described and illustrated, the results tabulated and plotted, and a Table of the specific properties of commercial carburets is given. In consideration of the great difference in the latent heat of evaporation, and the velocity of vaporization (deduced from the results obtained), it appears that it is necessary to increase

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the metallic mass of the carburettors, to give them a large surface of contact, and to impart to them a higher temperature in the case of carburetted alcohol, than in the case of the light petroleum spirits, the main object being to obtain perfect combustion by preventing the mixture falling to its point of saturation. For the same reason a motor driven with carburetted alcohol cannot be started at the ordinary temperature without imperfect combustion, and this affects the valves. In the case of fixed motors, the best remedy is to employ a little of the light petroleum spirit. On similar grounds it is bad to surround the cylinder of the motor with a large mass of cold water, for until this becomes sufficiently heated by the explosions, imperfect combustion must occur.

E. H. S.

A new Tachymeter. PULLER.

(Zeitschrift für Architektur und Ingenieurwesen, 1903, pp. 34, *et seq.*)

This instrument, which effects all that previous instruments of the same type can do, has the further advantage that readings can be taken on a staff held vertically, instead of on a staff held perpendicular to the line of sight, as is usually the case with this class of instrument. Moreover, the observed points can be plotted on tracing paper in the field, and can afterwards be transferred to the plan, when the weather is unsuitable for outdoor work, or whenever convenient. The main object of the instrument is to obtain the plans and levels of the observed points, without the necessity of noting the distances and horizontal angles, and thereby to enable the engineer to dispense with sketches, etc., and to avoid the labour of calculating and checking the results. At the same time, should the weather be unfavourable for paper-work, the observations for direction, distance and height can be taken in the usual manner if desired. The instrument consists of a horizontal plate, 42·5 centimetres (16½ inches) in diameter, mounted on a tripod of the usual kind. This plate is graduated to read horizontal angles, and at the centre is a vertical axis which carries the telescope on one side and the new projective apparatus on the other. The arrangement consists of graduated horizontal and vertical scales connected to the telescope and receiving motion from it, and by means of which the distances and heights can be read off and the observed points plotted by pressing a needle-point into the paper stretched upon the horizontal plate. The instrument is described and illustrated. It is stated that on average ground, fifty to sixty points can be plotted per hour.

E. H. S.

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Manufacture of Peat Charcoal. J. J. TYLVAD.

(Ingeniøren, Copenhagen, November, 1902, p. 311.)

One of the greatest technical difficulties in coaling peat is the spontaneous ignition of peat-charcoal at a temperature even below 150° C. or 300° F., on exposure to air; hence it is that quenching with water is not satisfactory. The best principle is to employ for the coaling the very gas driven off from the peat itself during the process, as is done in certain ovens for coking coal and in others for making wood-charcoal. At Oldenburg, in Germany, this principle has been carried out by Ziegler,[1] of Berlin, in the largest peat-coaling works thus far erected anywhere. The operation is there so conducted that more gas is given off from the peat than is required for coaling it, and the yield is 35 per cent. of peat-charcoal with 4 per cent. of tar. Although these two products, burnt as fuel, give out more heat than the peat, yet, owing to the high temperature at which the coaling is done, the advantage thus gained is hardly so great as the loss of heat in flues, etc.

The Ziegler ovens are upright, and their horizontal section is a flat oval or D shape; they are arranged in pairs, with their flat sides facing each other. Their curved backs are surrounded by flues, and a space is also left between them to serve as a flue; thus each pair exposes a larger heating surface to the fire than would a single oven containing the same quantity of peat. The lower half of every oven or retort is constructed of refractory stone, and the upper of cast-iron. The products of distillation are exhausted through an air-condenser, in which the tar and water are separated; the remainder of the impure gas, mixed with about 25 per cent. of carbonic acid, is led back direct, without passing through any gasholder, into the flues surrounding the ovens, where it is burnt, and thence discharged to the chimney. Air admitted beneath the ovens cools the bottom portion, containing hot charcoal; it is itself thereby heated in readiness for burning at the place where the gas is admitted into the flues, about midway up the height of the ovens.

As, however, the regenerative effect here realized is not carried so far as to cool down the charcoal sufficiently before the oven is drawn, its contents have to be carefully emptied into iron trucks, which are then covered up air-tight and left to cool out of doors. The tar water is acid, containing in solution acetic acid, ammonia, and methyl alcohol or wood-spirit; experimentally 1 m^3 yielded 30 kg. acetate of lime, 20 kg. sulphate of ammonia, and 10 kg. of wood-spirit: in other words, 10 gallons yielded 3 lbs. and 2 lbs. and 1 lb. respectively. The acetate of lime and

[1] Minutes of Proceedings Inst. C.E., 1901, vol. cxlvi. pp. 229 *et seq.*; *Ibid*, vol. cxlviii. p. 403.

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sulphate of ammonia are obtained by evaporating their solutions in pans, underneath which are led the products of distillation on their way from the ovens to the condenser. The acetate of lime is used for making acetic acid, and the sulphate of ammonia for manure. The tar differs in composition from that obtained from wood and that from coal. At ordinary temperatures it is about as stiff as butter. After being diluted with sulphuric acid, and washed with water until neutral, it is distilled in cast-iron retorts at 350° C. or 660° F., yielding 35 per cent. of crude oil and 55 per cent. of paraffin; the residue is gas and coke. When it has been left for some days to crystallize, the paraffin is pressed, first in a filter press, and then in a hydraulic press at 200 atm. into cakes of crude paraffin for further manufacturing processes. The oil expressed is mixed with the crude oil, purified with soda lye for creosote, and sold as gas-oil. In this way the following commercial products are obtained from the tar:—paraffin cakes 10 per cent., gas oil 58 per cent., and creosote oil 12 per cent.; the last is used for impregnating timber. Altogether 100 kg. (220 lbs.) of tar realize from 7 to 8 marks.[1]

The practical working of the Ziegler plan at Oldenburg furnishes the best proof of the importance of the principle on which it is based. The aggregate calorific value of the gas and tar is more than 30 per cent. of that of the peat. As the coaling of the peat is here dependent upon the gas evolved, the manufacture of gas, rather than of peat-charcoal, might be said to be the object aimed at.

There remains however, in the Author's opinion, a further improvement yet to be realized, by a practical solution of the problem of coaling the peat at so much lower a temperature as to avoid driving off in the process so large a proportion of its combustible constituents. This is the aim of several recent plans. At the outset of the coaling it is mostly water only that is driven off, up to about 150° C. or 300° F. Under 200° C. or 390° F., which is the temperature most suitable for coaling the peat, it seems probable that the combustible gases are given off. Coaling at so low a temperature would be impracticable in retorts; and recourse must therefore be had to some method of exposing the peat to the direct action of a gaseous mixture having that temperature, and, like smoke, containing no oxygen. Various considerations affecting such a mode of procedure are dealt with at some length by the Author. The advantage arising from the diminution in weight and bulk, which the peat undergoes in coaling, cannot be realized unless the coaling can be done so economically that the aggregate loss of heat during the process is outweighed by the enhanced richness of the charcoal so obtained. In coaling experimentally at 200° C. or 390° F., the yield of charcoal weighs between 50 and 60 per cent. of the air-dried peat,

[1] It is not stated whether these are Danish marks of about 4½*d.*, or German of 11½*d.*—A. B.

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while the heat expended in the process represents from 10 to 20 per cent. of the peat. The reduction in bulk is somewhat less than 50 per cent.

A. B.

Asphalt Refining. W. R. Crane.

(Mines and Minerals, vol. xxiii., 1903, p. 337.)

Within the last few years asphalt deposits of considerable extent have been opened up in the Indian Territory, United States. At Tar Springs the deposit occurs in a basin about a mile in diameter, the asphalt being met with in sands and sandstone which it has thoroughly impregnated. The overburden is removed, and a thin capping of barren sandstone blasted off. The bed is then loosened by ploughs drawn by teams of four or six mules, and excavated by wheeled scrapers. The sands contain 10 to 14 per cent. of asphalt, and 3 to 6 per cent. of heavy oil. The asphalt sands are tipped and shovelled to a feed bin, and conveyed thence to a disintegrator which is heated by steam to facilitate the passage of the adhesive asphaltic material. The broken-up material is raised by an elevator to the concentrating apparatus in the upper part of the building. The material is discharged into a hopper which is provided with a shoot, through which it passes to the separators. These may be described as one-celled Spitzlutten, with washing trommels, and an upper and a lower endless chain discharging conveyor. The finely broken up asphaltic sands enter the feed-hopper and pass to the trommel which is driven at a speed of 19 revolutions a minute. Here they are completely disintegrated in a bath of warm water. The associated heavy oil adheres to the asphalt and buoys it up, while the sands, freed from both asphalt and oil, and washed by the warm separator water, escape through the meshes of the wire covering of the trommel and settle at the bottom of the separator, whence they are discharged by the under-conveyor. The asphalt and oil rise to the surface of the water, and are discharged by the upper conveyor. A partition placed at the feed-end of the trommel prevents the lighter materials from passing away with the sands. This method of separation was devised by Mr. R. V. La Grand, and is similar to the Elmore oil process of concentrating ores. The elimination of water and oil from the asphalt is effected by evaporation. The total loss in concentrating and refining varies from 4 to 6 per cent. The refinery cost £8,000. The cost of mining is 4d. per cubic yard, and that of refining about £2 per ton. The plant is designed for a capacity of 25 tons, finished product, per day of 24 hours.

B. H. B.

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Mica Mining in India. T. H. Holland.

(Memoirs of the Geological Survey of India, vol. xxxiv., 1902, p. 11.)

In this monograph, which covers 121 pages, the Author describes the Indian occurrences of mica of commercial value. Chapters are devoted to its mineralogical and chemical characters, geological occurrence, geographical distribution, uses of mica, and mining practice. A bibliography and an index to localities are appended. In 1900 there were in India 131 mines employing 9,517 persons at work on mica. The total production amounted to 916 tons, more than half of which was raised in the Nellore district in Madras, which is outstripping Bengal in the development of its mica resources. The mineral occurs as a constituent of granite-pegmatite. Crystals of muscovite mica have been obtained in the Nellore district measuring 10 feet across the basal planes, but usually they are much smaller. In Bengal, the pegmatites have intruded into the schists in the form of sheets and lenticular masses parallel to the foliation, and less often as dykes cutting obliquely across the schists. In the Madras area the masses are usually in the form of intrusive sheets. Two systems of mining have been followed. In Nellore the mineral is raised in open quarries the slope of whose sides is determined by the angle of repose of the surrounding schists; in Bengal the mica is followed from crystal to crystal along tortuous holes. The former practice is capable of improvement; the latter is most extravagant and primitive, and should be replaced by methods employed elsewhere for mining mineral veins.

B. H. B.

Pendulum-Propeller Trials. H. C. Vogt.

(Ingeniøren, Copenhagen, November, 1902, pp. 297–301.)

In view of the good results obtained with the pendulum propeller in previous trials by Professor Borch, the Russian Admiralty ordered it to be tried by Commander K. Nielsen in a captain's sea-going launch, 30 feet long, 7½ feet beam, drawing 2½ feet of water, and fitted with a benzine motor, which, at 750 revolutions per minute, gave 16 HP. The motor speed was reduced by spur gearing to 207 double oscillations per minute of the rocking-shaft carrying the propeller, which swung through 75°, or 37½° on each side of its centre position. In a number of runs in open harbour, averaging 6½ minutes each, the speed attained was 7½ knots when the propeller was making from 150 to 155 double swings per minute; it rose to 7·7 knots with 180 swings, but 200 produced no further increase of speed. If the loss in transmission were only 16 per cent., against as much as 40 per cent. in motor-cars, the power expended on the propeller at 7½

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knots would be about 10 HP. Unfortunately the transmission, besides being roundabout through an intermediate shaft running along one side of the boat, was in such bad order, that it must have absorbed fully one-third of the power of the motor. Nevertheless at 6 knots the consumption of benzine was as low as 4·9 lbs. per hour: an economy scarcely reached with the screw which had been displaced by the pendulum propeller. At this speed, corresponding with 112 double oscillations per minute, the stern of the launch was swung 3 inches to either side, involving a serious loss of power in swinging so large a boat to such an extent about twice per second. At 7 knots the side movement was felt as a tremor. Hence, for steady running, two symmetrical propellers are wanted, swinging counter to each other; and a simple arrangement of double-expansion engine for driving them is described and illustrated. A photograph is given of the Russian boat when making 7½ knots with six men on board; and a full description of the propelling machinery, with illustrations.

Previous trials[1] were made by the Author with a boat of his own, fitted with a pendulum propeller, without rigging, and with only two-thirds ballast; carrying four men she weighed about 2,700 lbs., and was fitted with a jolly-boat motor identical with those generally used with the screw in fishing-boats which carry one man each, and weigh only about 1,650 lbs. The same motor in the fishing-boats could not drive the same weight at the same speed with the same power as in the boat driven by the pendulum propeller. During ten years that the pendulum propeller was worked by manual power only, it was found to be an ideally perfect sculler, superior to a screw driven by the same means.

A. B.

Cavitation. J. A. Normand.

(Comptes rendus de l'Académie des Sciences. Oct. 1902, p. 662.)

The loss of efficiency in screw-propellers due to cavitation, has recently forced itself upon the attention of marine engineers. At high speeds the loss due to this cause appears to outweigh all other sources of loss, and indeed when cavitation is fully produced, no increase of power, however great, can increase the speed. The momentum imparted to the water by the screws, measures the resistance of the ship, and if the velocity be sufficiently great to produce cavitation, then in order to avoid this source of loss, and at the same time maintain the speed, the other factor, namely the mass of water sent astern, must be increased. Now this mass is proportional to the propelling surface; whence the author deduces the following simple rule: The propelling surface should be

[1] The construction and action of the Pendulum Propeller were described in "Ingeniøren," September, 1899, pp. 249–250.—A. B.

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proportional to the product of the resisting surface into the speed, or more exactly to the quotient of the power by the square of the speed. This may be expressed[1] symbolically thus: $n \Delta r^2 \frac{2}{4} (sic) = j \frac{F}{V^2}$, the left-hand side of the equation representing approximately the propelling surface, where n is the number of screws, supposed identical, Δ the diameter of the screws in metres, r the ratio of the total developed surface of the blades of a screw to the area of the circumscribing circle, F the maximum horse-power, V the speed of the ship in knots. Experience shows that the coefficient j must never be less than 0·60, and may with advantage exceed 0·80. This rule has received frequent verification during the past three years; it explains the sometimes abnormal fall, sometimes exceptional rise of efficiency, which the form of the hull alone cannot account for. Thus three identical cruisers of 14,300 tons and 31,000 horse power, with similar screws were tested at sensibly the same maximum speeds. The curve of work expressed as a function of the velocity, suffers an abnormal fall at the maximum speed, and shews that an increase of one knot would require an increase of 15,000 to 20,000 HP. The screws of one of these ships having been replaced by others of considerably greater propelling surface, an increase of more than one knot was obtained without increase of power, and without any abnormal fall in the curve of work. In the first case the coefficient j did not exceed 0·43, whilst with the enlarged screws it reached 0·60. Thus, a simple change of screws, the cost of which was hardly $\frac{1}{300}$ of the cost of the ship, was sufficient to give a result which would have cost at least thirty times more if obtained by increasing the horse-power and dimensions of the ship.

In experiments on models, it has been believed that the laws of similarity hold almost exactly, provided that the speeds are proportional to the square root of the linear dimensions. This is true, except as regards cavitation, unless indeed the atmospheric pressure is reduced in proportion to the linear dimensions. The speed of the water in the suction channel is not reduced in proportion to the linear dimensions: this speed is caused by the external pressure, together with that due to the height of the water-line above the screws. This last height is indeed proportional to the linear dimensions of the model, and would, if it acted alone, produce a speed proportional to its square root, that is to say, the homologous speed of the model; but by far the most important cause of the velocity in the suction channel, is the external pressure of the atmosphere, which is not reduced in any existing experimental tank.

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[1] Approximate rules for the calculation of propulsive surface. Bulletin de l'Association technique maritime, 1899.

E. H. S.

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Further Experiments with Ozone for Water-purification.[1]

PROSKAUER and SCHÜDER.

(Zeitschrift für Hygiene, vol. xlii, 1903, p. 293.)

An account is given of tests, carried out by the Authors at the Wiesbaden Works, constructed by Messrs. Siemens and Halske, for purifying water by means of ozone. After a brief description of the works and plant, it is pointed out the water-supply is obtained from springs situated in a district liable to be inundated by the Rhine when in flood, and therefore capable of becoming polluted. When submitted to chemical tests this water proved to be much purer than that supplied to the works at Martinikenfelde. Certain preliminary tests carried out by the contractors are described, and the results are set forth in a Table, and it is shown that the untreated water was from time to time extremely pure. On account of the relatively low percentage of germs originally present, the Authors arranged to infect the water-supply on three occasions with special cultivations of germs derived from previous experiments; the percentage of germs per cubic centimetre was thus made to range from 26,000 to 55,000 in the untreated water, while after exposure to ozone the numbers varied from 5 to 12 germs per cubic centimetre. The methods of infecting the water with various kinds of bacteria and of testing the water after treatment are fully set forth, and in all cases the Authors took the precaution to withdraw a large volume of water for testing at such a slow rate of delivery as to obtain a sample of the yield during not less than 8 minutes. They sum up their conclusions as follows: These further results coincide in all points with those first obtained, and prove that, even when the water is artificially impregnated with large numbers of germs, the sterilization is invariably satisfactory and the water is rendered fit for drinking purposes. Ozone furnishes a safe and reliable means of destroying germs in water even when large volumes are treated.

G. R. R.

Hamburg Waterworks. RUD SCHRÖDER.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, p. 785.)

The first waterworks for the city of Hamburg were completed in the year 1848, their construction having been brought about by the great fire of 1842 which had proved the utter insufficiency of the water supplies provided by the various private companies. The supply was obtained from the river Elbe at a point about 2

[1] Minutes of Proceedings Inst. C.E., vols. cxl. p. 338; cli. p. 480.

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miles above the city boundary, being pumped into a high-level reservoir from which it flowed by gravitation to the town. This source of supply was continued, the machinery and reservoirs being added to from time to time, until the year 1893, when new works were opened at Billwärder Island about 1½ mile further up stream. At these new works the water is pumped from the river into 4 settling reservoirs having a total area of 16·8 hectares (41·5 acres) and an available cubic capacity of 300,000 cubic metres (66 million gallons). From these reservoirs the water flows by gravitation to filters on the Island of Kaltehofe near the old source of supply, and after passing through these filters, the water is led into a clear water well at Rothenburgsort, from whence it is pumped up as before to the high-level reservoirs from which the town draws its supply. In the machine house at Billwärder there are six horizontal compound steam-engines, each of which when running at 45 revolutions per minute, can lift 1900 cubic metres (418,380 gallons) per hour the height being about 4·3 metres (14·1 feet). During the year 1900 the average quantity of water pumped per day was 141,142 cubic metres (31 million gallons), the mean height of lift being 4·3 metres. On the plant being tested before being taken over from the contractors it was found that the steam consumed per theoretical pump-HP. per hour was 13·46 kilograms (29·6 lbs.).

There are 22 filters at Kaltehofe the total area of sand being 17 hectares (42 acres). The filters are not enclosed within walls, which would have required deep and expensive foundations, but have simply pitched slopes. The water passing through the filters per square metre per hour is 64 litres (1·31 gallon per square foot). Bacteriological tests are regularly carried out by officials of the City Hygienic Institute and also separately by scientists attached to the service of the waterworks.

The water is not laid direct on to the house taps but first runs into tanks from which it can be drawn as required, and the supply is intermittent. Taking the number of people within the district of supply as 699,500, the maximum quantity per head per day during the year 1900 was 218 litres (48 gallons), the minimum 142 litres (31·3 gallons) and the mean 174 litres (38·3 gallons).

J. G.

Water-Tank with Hemispherical Bottom at Washington Heights, Chicago.

(Engineering News, 25 December, 1902, p. 544.)

This district of Chicago is now supplied with water from Lake Michigan by means of an 8-inch and a 16-inch main, which deliver into three storage reservoirs. A re-pumping-station is employed to deliver water for the high portion of the district, containing 10,000 inhabitants, into an elevated tank having a capacity of

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180,000 gallons. Its upper part is cylindrical, having a diameter of 28 feet for a depth of 30 feet, the steel plates of which it is built being $\frac{1}{4}$-inch thick at top and $\frac{3}{8}$-inch thick at the base, and it has a hemispherical bottom of $\frac{5}{16}$-inch plate riveted directly to the cylindrical sides. The tower is composed of four columns on concrete foundations, divided vertically into three panels by two horizontal lines of struts and braced by diagonal rods. Each column consists of two 15-inch channels set back to back with a cover plate 17 inches wide on the inside and a lacing on the outside.

Round the base of the cylindrical portion of the tank is a circular balcony girder 36 inches wide, supported by gusset plates from the columns; this takes up any horizontal strain and serves as a footway. The columns terminate at the top with heavy angles extending above the channels which are riveted directly to the cylindrical sides of the tank, a $\frac{5}{16}$-inch plate, 48 inches wide, being placed between each column and the shell of the tank. In this way the load is transmitted directly to the columns without any necessity for a supporting girder.

A. W. B.

A new Method of Heating Buildings. HERMANN FISCHER.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, p. 1363.)

In the ordinary hot-water heating, if the boiler fire is forced in order to supply extra heat in times of very cold weather, it often happens that hissing and rattling noises issue from the pipes, being due to the presence of small quantities of steam. These small volumes of steam in the ascending pipes, however, aid the circulation of the water very considerably. Taking the case of water alone at 100° C. in the ascending pipes and water at 60° C. in the return pipes, the difference of pressure is equivalent to 24 millimeters of water in 1 meter height. If however one thousandth part of the water is converted into steam, the difference of pressure which is effective in inducing circulation is increased to 600 millimetres. A system taking advantage of these considerations has been simultaneously invented by a German and a Danish engineer. At any point in the system of piping a short length of vertical piping is arranged with a closed vessel at the bottom end, and a tank open to atmospheric pressure at the top end. Into the lower vessel a steam-pipe is led from which steam passes into the water in the pipe, not directly, but through layers of wire gauze, this arrangement being effective in avoiding the noises which would be produced if the steam came into direct contact with the water. The mixture of steam and water passes into the upper vessel and from this the radiators are supplied. This vertical column of steam and water constitues the driving force of the whole system. The

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advantages of the system are that smaller pipes are required than with purely hot-water systems, noise is entirely avoided and it is not necessary that the boiler should be at a lower level than the radiators. As regards cost, the system comes between low-pressure steam and the ordinary hot-water heating.

J. G.

The Paris Cold-storage Depôt. DANIEL BELLET.

(La Nature, 14 February, 1903, p. 164.)

Under the auspices of the Cold Storage Company of the Central Markets, vast cellarage has been constructed beneath the Paris Commercial Exchange. The cellars have been formed in two storeys, one under the other, and have a capacity of 226,000 cubic feet. The difficult work of executing this double tier of cellarage was carried out without interfering with the buildings above ground, and caused no stoppage of business in the Paris Central Market. The temperature in the main cellars can be kept at 12° C. below zero, by compressed ammonia machines on the Lindé system. The cold-producing machinery is used to chill the air conveyed into the cellars. All the machinery is in duplicate: the engines are each of 50 HP., and steam is supplied by three Babcock and Wilcox boilers. The walls of the chambers and vaults are coated with white enamel paint, and are covered with layers of powdered cork. All the partitions are formed of two thicknesses of 2 inch boarding, with 9 inches of powdered cork between them, and a similar protective coating is placed round all external walls, columns, etc. In addition to the main cellars there are numerous small lock-up cellars, which can be rented by shopkeepers and others, and kept at any desired temperature; these are suitable for preserving game, flowers and eatables of all kinds. The entire establishment, which is adapted for the storage of 10,000 tons, is lighted by electricity. Illustrations are given of the machinery and of the interior arrangements and fittings.

G. R. R.

Strength of Tall Chimneys. PREUSS and LANG.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, p. 1,321.)

A recently issued ministerial circular of the German Government directs that where, in the calculation of the greatest stresses on the lee side of chimney stacks, the brickwork is assumed to possess no resistance to tension, the opening of the joints shall not be supposed to extend beyond the centre of gravity. Taking the case of the chimney of circular section, calling R and r the external and

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internal radius respectively, σ the stress on the outside, u the stress on the inside of the ring, G the weight of the chimney, ar the distance of the centre of gravity of a cylinder hoof of radius r from the centre of the complete circle, and putting c for the distance from the centre of the circle to the point of action of the resultant stress, for which stress the opening of the joints is limited to the extent of half the diameter of the section, the value of c is determined by the following two equations:—

$$\frac{2}{3}R^2\sigma - \frac{2}{3}r^2u - G = 0;$$

$$\frac{2}{3}R^2\sigma\, a\, R - \frac{2}{3}r^2u\, a\, r - G\, c = 0.$$

The most useful form of the formula derived from these two equations, from which to determine c, is as follows:—

$$\frac{c}{R} = a\,\frac{1-\left(\frac{r}{R}\right)^4}{1-\left(\frac{r}{R}\right)^3}.$$

The following short table is useful for rough calculations:—

$\frac{r}{R}$	0	0·5	0·6	0·7	0·8	0·9	1·0
$\frac{c}{r}$	0·589	0·631	0·654	0·682	0·713	0·748	0·786

The second of the two Authors further discusses the subject, giving approximate formulas for the exact ones of the first Author and also for the maximum stresses for the case when the deviation a of the resultant stress from the centre, is less than c. He also supplies numerical tables to assist in the actual design of chimneys of circular, octagonal and square section.

J. G.

A Water-Power Electricity Station at Burgos (Spain).

(Revista de Obras Publicas, vol. l. p. 536.)

Upon the River Ebro are three waterfalls which are now used for the production of power; one fall at Cereceda, above the confluence of the Nela, has a height of 72 feet and a volume of 250 cubic feet of water per second, corresponding to 1,540 HP. Below the confluence of the Nela, at Quintanamartingalindez, is a second fall

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of 65 feet, and a volume of 350 cubic feet per second, or 2,000 HP.; and at Sobron there is a third fall of 130 feet, and a volume of 350 cubic feet per second. The energy will be transmitted to Bilbao, which is at a distance of 42 miles, 40 miles, and 36 miles from the falls in the order named.

At the first fall there is a dam 16·4 feet high and 125 feet long, and an open canal 7,630 yards long, excavated in solid ground and carrying the water to the power-house. At the second fall the dam is 16 feet high and 354 feet long, and was almost finished at the time of writing; the canal is 11,445 yards long. It was expected that the power-house would be finished at the end of 1902, and that electricity would be supplied in March, 1903. The total cost is estimated as £126,000, and the power available will be about 3,570 HP. The cost of the plant and works per unit delivered is given as £35·3, and the annual cost per unit as £1·6. The third fall is not yet dealt with, but there will be a dam 13·2 feet high, 246 feet long, and the canal will be 13,625 yards long. There will be three short tunnels upon this canal, the longest measuring about 82 yards. It is expected that the works at this third fall will be finished in 1903. No details are given of the electrical plant.

E. R. D.

The Water and Electrical Power System of the Pike's Peak Power Company, Colorado. W. P. HARDESTY.

(Engineering News, 1 January, 1903, p. 2.)

This is a scheme to take advantage of the rapid fall of the streams of water flowing from the slopes of Pike's Peak. The development of one of these streams, the West Beaver creek, has already been effected and the plant operated since 1901. The dam forming its reservoir is located 5½ miles east of the town of Victor and 10 miles south of the summit of Pike's Peak. The reservoir has a surface area of 130 acres and will hold 637 million gallons of water, its top water level being 9,081 feet above sea level. The dam, of the steel-faced, rock-filled type, is 405 feet long on the top, 148 feet wide at the base and 20 feet wide at the top; its height from the granite rock foundation to the overflow level is 70 feet. The steel plates forming the inside face, which is sloped at an angle of 30° to the vertical, are depended upon to keep the dam watertight. They are 15 feet by 5 feet, and ½ inch thick at the bottom reducing to ¼ inch at the top, and are riveted together horizontally with butt strips and vertically by a pair of 4 inch by 5 inch by ½ inch angle bars. The 5-inch flanges of each pair of angle bars project into the reservoir and are riveted together at their outer extremities with an iron strip, 2 inches by ⅜ inch, placed between them, so that the effect of expansion and contraction of the plates is allowed for by the spring at these joints. The

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bottom and end plates have two rows of angle bars, 5 inches by 8 inches, riveted to them, and are embedded in concrete placed in a trench cut in the rock. A space of about 6 inches next to the facing is filled with fine material thoroughly packed, and next comes loose rock of all sizes so that the spaces between the larger blocks are filled with the smaller pieces. The overflow crest, 3 feet below the top of the dam and 50 feet long, is cut through the granite formation. The outlet is a wooden stave pipe, 30 inches diameter, which passes through the dam embedded in concrete and extends 240 feet into the reservoir, a strainer being formed at its end by slits 2 feet by ½-inch cut into the staves. The conduit pipe is carried along the cañon side to the power-house, a distance of 23,000 feet, a benching 6 feet wide having been excavated for its reception. Trestles of hewn timber are used for carrying the pipe over the dips. The staves composing the pipe are of Californian redwood milled to 1½-inch thickness and bound together with steel bands connected by cast-iron lugs. The bands are spaced, according to the pressure, from 8 inches to 2¼ inches apart; the maximum static pressure is 220 feet in the wooden stave portion of the pipe. The final portion of the conduit has a very steep fall, and consists of a steel pipe 29 inches diameter varying in thickness from ¼ inch at its beginning to ¾ inch at the power-house. It is anchored at intervals to prevent it sliding down the steep slope, by steel cables passing round the pipe below a joint and attached to bolts in the solid rock.

The hydraulic equipments in the power-house consists of 4 units of two steel disk wheels, 66 inches in diameter, keyed to the same shaft, of the Pelton wheel type; the nozzles of the two wheels being of different sizes so as to allow of varying the power. A 1-inch nozzle under the pressure of 1,160 feet develops 236 HP., the wheels revolving at 450 revolutions per minute. The efficiency of the wheels is 83 per cent. They are directly connected to the electric generators.

A. W. B.

Variable-Speed Polyphase and Direct-Current Motors.

Dr. Behn-Eschenburg.

(Schweizerische Bauzeitung, 1902, p. 167. 14 Figs.)

The Author observes, that at the Oerlikon works polyphase motors were built in 1893, in which the number of poles could be altered by a special method of switching. The particular method is described and illustrated, and it is pointed out that of course the simplest arrangement was to halve the number of poles. The switch-gear used about 1894 is shown, and at that time the Gramme ring winding was generally adopted. In recent years, however, drum-winding has been almost exclusively used for polyphase motors. The modern method is to wind in the same grooves

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of the rotor, and also sometimes in the same grooves of the stator, two separate windings, one of which is suitable for one number of poles and the other for a different number of poles; this method affords great advantages. The switch-gear consists of two ordinary triple pole-switches, and the Author describes the windings in detail.

As an example of the successful use of the system two examples are given, one of a polyphase-motor built for a normal speed of 1,450 revolutions per minute at 50 periods, and developing 8 HP.; it weighs about 484 lbs., and the diameter of the armature is 9·45 inches. There are two windings, one suited for 6 or 12 poles, and the other for 4 and 6 poles; it is intended for driving a lathe, and the results of elaborate tests are given in tabular form. The switching device enabled the winding to be changed from star to triangle winding. The speeds with star winding were 500, 750, 1,000, and 1,500, and the respective efficiencies at full load, 72 per cent., 73 per cent., 85 per cent. and 86 per cent., while with triangle winding the speeds were 1,000 and 1,500, and the efficiency in both cases 80 per cent., the pressure in all cases being 190 volts. Direct current machines are built to give similar results, and for one machine the results are tabulated. It is intended to develop 3 HP. with 130 volts.

The speeds were 1,500, 1,000, 750, 500, and 350 revolutions per minute, and the efficiencies at full load respectively 66 per cent., 72 per cent., 73 per cent., 74 per cent., 73 per cent.

The great advantage is in either case the absence of all gearing or speed cones upon the lathes.

E. R. D.

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150 *HP. Polyphase-direct Rotary Transformer.*

(Schweizerische Bauzeitung, vol. xl. p. 197. Eight Figs.)

The firm of J. J. Rieter and Company in Winterthur have recently built a special rotary transformer for the Royal Palace in Madrid which contains several novel features. The apparatus comprises an asynchronous polyphase motor of 150 HP., and two direct current dynamos each of 50 kilowatts. The motor is supplied with current at 3,200 volts to 3,400 volts, and the two dynamos deliver current at 125 volts to 180 volts, and feed a three-wire network with a secondary battery and a potential of 250 volts across the outers.

As space was very limited, only two bearings are used, the armatures of the dynamos being overhung, thus affording better access to the commutators. The chief dimensions are as follows: the polyphase motor is of the ten-pole type, with a diameter of 33 inches between poles, and 54·72 inches outside the case. Both dynamos are of the six-pole type, with armatures 20·3 inches

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diameter. The total length of the group is 9 feet 10 inches, and the weight 8 tons.

The efficiency of the group is almost constant from half to full load, and is at its maximum of 84·5 per cent. at three-quarters load, with 3,200 volts on the motor and 125 volts at the dynamo terminal. With 3,400 volts at the motor, and 140 volts and 3u0 amperes at the dynamos, the efficiency at full load is 85 per cent.

From no load to 25 per cent. overload there is no sparking, and no necessity for shifting the brushes. The rise in temperature after

1 hour at	125	volts	and	400	amperes,
1 „	180	„	„	300	„
15 minutes at	125	„	„	600	„

in the dynamos was 35·7° C. in the iron of the armature, 35·7° C. in the armature windings, and 34·7° C. on the commutator.

Characteristic curves and sections of the machine are given in the original.

E. R. D.

Changes in the Construction of German Telephone-Cables.

(Archiv für Post und Telegraphie, 1902, p. 498.)

The Author refers to a Paper which appeared in the "Archiv," No. 19, of 1901. The standard 7-way cable for underground work has been superseded by a 10-way cable. The construction of the new cables is essentially similar to that of the older type; but the wire is now 0·8 millimetre diameter instead of 0·7 millimetre. The lead covering is of the same thickness as in the older type, that is to say for 10 pairs of ways the lead is 1·7 millimetre thick if there is no armouring, 1·6 millimetre thick if the armouring is open, and 1·5 millimetre thick if the armouring is closed. The armouring consists of iron wire of trapezoidal cross-section. The resistance per kilometre at 15° C. must not exceed 37 ohms, and the insulation resistance for the same length and temperature must be at least 500 megohms, and the capacity must not exceed 0·055 microfarad; the last is the value for one way on the assumption that during the test the remaining ways are all earthed. The Paper contains a series of tables giving details of the cables in use.

E. R. D.

Telephone Cable-Conduits with Single Ways. Rühl.

(Archiv für Post und Telegraphie, 1902, p. 213. Figs.)

The Author describes the changes from the overhead system of telephone wires to the underground system. At first ordinary cast-iron socketed pipes were used, and these were satisfactory so

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far as life was concerned, but unsatisfactory because it was found undesirable to draw a number of cables into one pipe, as the lower cables could not be drawn out. There are in some of the older conduits cables of three qualities; (*a*) cable with 28 single conductors, cotton and tin-foil wrapping, and earth wire-resistance 26 S.E., and capacity 0·25 microfarad per kilometre; (*b*) cable with 56 single conductors, air and paper insulation, tin-foil and earth wires, resistance 23 S.E. to 30 S.E., and capacity 0·08 to 0·12 microfarad per kilometre; (*c*) cable with 28, 56, 112, 224 double conductors, air and paper insulation (without tin-foil and earth wires), resistance about 37 ohms, and capacity 0·055 microfarad per single conductor kilometre.

While the product of capacity into resistance is 6·50 for class *a*, the figure is 2·035 for class *c*.

The Author then proceeds to describe the various types of conduits, and a large number of illustrations are given in the original. Cement-concrete conduits have been largely used and also various forms of salt-glazed tubes and iron pipes. In comparing the relative advantages of the various types, the Author points out that the cost of cast-iron pipes is in most cases prohibitive. Cast-iron pipes cost in 1901, in Berlin, 29·1*d.* per yard, while flat cement conduits with 3 ways cost 28·6*d.* to 32·7*d.* per yard, and therefore the cost per single way was only 9·6*d.* to 10·9*d.* per yard, and of course the price becomes still lower where the cement sections have more ways. Cement and stone-ware are also preferable to iron, because they are uninfluenced by stray currents and by chemical action. The system which appears to find the greatest favour at present is the Halberger, which consists of cast-iron pipes with sockets, having externally a hexagonal form, and these are built up like the cells of a hive; this system is used when passing over bridges, etc., and where speed in laying is essential. In all other cases the flat sections of concrete with round ways are adopted.

E. R. D.

Siemens and Halske's Improvements in Telephone Exchanges.

DANKWARDT.

(Archiv für Post und Telegraphie, 1902, pp. 655, 687. Twenty-seven Figs.)

In 1902 certain telephone exchanges belonging to the German postal service were for the first time supplied with Messrs. Siemens and Halske's improved system of glow-lamp annunciators, arranged so that the microphones can be supplied with current either by separate batteries or by a central secondary battery. The Author describes the advantages and disadvantages of the system, and considers that the former preponderate. The apparatus is made in the form of a table with flat top, instead of

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the vertical frame employed when the old type of magnets were used, and illustrations are given of an installation with 8,000 jacks; the table form requires two floors, one upon which the operators sit, and the other, below, to afford access to the wires and connections. The lamps are made for a pressure of 12 volts, and the Author describes the connections, which are also illustrated by diagrams, one of which shows a subscribers' station, consisting of single line and earth return central microphone battery and magneto-call; another shows a metallic return with subscribers' microphone battery and magneto-call.

After describing the direction of the currents and the routine in the exchange, the Author deals with a board for trunk lines between exchanges. This apparatus is built in table form as already described, but a double floor with clear space of about 6 inches to 10 inches is sufficient. The table accommodates four operators, each in charge of two trunk lines. Call-lamps are used, as upon the subscribers' boards, and these lamps are switched on by two relays, one for calling of 600 ohms, and the other for holding of 100 ohms, the latter in series with the first. As a rule, one battery is used common to all the lines, and this has a high resistance of from 1,000 to 2,000 ohms.

The whole of the connections are carefully described in detail with the aid of diagrams. The new form of apparatus appears to have given satisfaction, and it is found best to use batteries of 10 volts with the 12-volt lamps in order to obtain a long life for the lamps.

E. R. D.

Strength of Struts. A. OSTENFELD.

(Zeitschrift des Vereines deutscher Ingenieure, 1902, p. 1858.)

The Author first considers Tetmajer's treatment of the strength of eccentrically loaded struts, agreeing with the central idea of Tetmajer's formula, but rejecting the formula itself for the following:—

$$\sigma = \frac{\sigma_{max.}}{1 + \frac{f_o}{k} + a\left(\frac{l}{i}\right)^2}$$

σ denotes the average stress over the cross section of the strut, with which is co-existent the maximum fibre stress σ_{max}, f_o is the original eccentricity of the point of application of the load, l the free length of a column having hinged ends, i the radius of gyration, k is the radius of the kern of the section on that side towards which the load is applied. Both Professor Tetmajer and the Author agree in stating the safe load on a strut as 1/m th of the load that would cause fracture of the strut. This is in contradistinction to the view that the load to be allowed is that which causes an extreme fibre

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stress of 1/m th of the ultimate tensile or compressive strength. In the practical application of this formula the values of σ_{max} and a are required. The values of σ_{max} are calculated from experimental determinations of the average stress at fracture, and may be denoted by σ_B. a is equal to $\sigma_B/8$ E. As the formula is intended to be applied beyond the limit of elasticity it is better to regard it as purely empirical, and to determine the value of a solely from the point of view of making the formula give results agreeing with experiment. For mild steel the value of σ_B, calculated from Tetmajer's experiments, is 3363 kilograms per square centimetre (21·4 tons per square inch) and of a, 0·00018. For wrought iron a is the same, while σ_B becomes 3030 kilograms per square centimetre (19·2 tons per square inch). The Author further attacks Tetmajer's straight line formula for centrally loaded struts. The determination of the area and form of the cross section of a strut is also entered into and a systematic method worked out, tables being given to aid in the proper selection of the most suitable sections. J. G.

Testing Hard Lead. F. W. Küster, P. Siedler, and A. Thiel.

(Chemiker Zeitung, 1902, vol. xxvi. p. 1107.)

The analysis of hard lead is one of the most frequent and most tedious operations at many smelting works. As lead and antimony are the only metals to be considered, the others being present usually in inappreciable quantities, it was thought that the proportion of antimony could be ascertained from the specific gravity, for the specific gravity of lead is 11·37, while that of antimony is 6·69. Experiments gave very satisfactory results. It was found that, if care be taken to cast a test-piece free from cavities, a high degree of accuracy is obtainable. Hard-lead with 20 per cent. of antimony has a specific gravity of 9·977, and the specific gravity changes 0·060 if the proportion of antimony changes 1 per cent. By this method of calculation, a skilled workman can analyse thirty samples of hard-lead in a day with a probable error of only 0·05 per cent. in the antimony contents.

B. H. B.

The Plasticity of Clays. B. Zschokke.

(Bulletin de la Société d'Encouragement pour l'Industrie Nationale, 30 November, 1902, p. 619.)

The industrial value of the various descriptions of clay is closely connected with certain properties which are peculiar to such materials; these may be described as their capacity for being moulded (*formabilité*,) or their "plasticity." These characteristics

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are well understood, and relate to the fact that when made up with a certain definite quantity of water, the clays may be formed into a fat, more or less ductile, pasty mass, which may undergo very extensive alterations in shape without loss of cohesion. The chemical basis of most descriptions of clay is the hydrated disilicate of alumina, but the chemical composition does not indicate the degree of plasticity in any given sample of clay. The Author discusses the steps taken at different times to define the phenomena connected with plastic action, and sets forth the opinions of Aron, Seger, Olschewsky, and others, as also the methods which have been proposed by various experimenters to determine or to measure the plasticity of clays. Rejtö was the first who attempted to construct a theory of plasticity on a mathematical basis, and his opinions are here cited together with graphic diagrams to explain the action of the molecules when matter is subjected to deformation. The Author shows that in all experiments with moist clays, it is essential that the paste should possess a uniform degree of consistency. To obtain this, entails the addition of a variable quantity of water to suit the particular properties of each substance tested, and it would seem that the necessary amount of water to temper the clay can best be estimated by rolling it with perfectly clean hands, and by gradually driving off the surplus water from a weighed sample until the proper condition of the mass to roll between the hands is reached. This fitness for treatment can thus be ascertained with great exactness by a number of different operators. The mode of preparing test-cylinders 1·18 inch in diameter, and 2·36 inches high is explained, and these cylinders were compressed or flattened in an Amsler press, but many different modes of testing are here illustrated and explained. The Author ultimately concluded that the best results were obtained by rupturing clay cylinders which issued from a nozzle in the same way as pugged clay is delivered from a brick press. The cylinders were 0·99 inch in diameter, and 1·96 inch in length.

Numerous photographs are given of the forms of the ruptured cylinders together with tables of the results of the tests, accompanied by graphic diagrams. Micro-photographs are appended of various descriptions of clays tested. In conclusion the Author states that the property known as plasticity is not peculiar to clays, but is possessed by any body, having a degree of cohesion as complete as possible, but capable of suffering a large amount of permanent deformation without by such treatment losing the cohesive strength which it originally possessed. In the case of clay, this property is very intimately connected with the marked affinity, chemical or physical, for water, and with the amount of water which any given sample can absorb. It depends also on the extremely small dimensions of the grains of clay.

G. R. R.

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The Permeability of Mortars. H. Le Chatelier.

(Bulletin de la Société d'Encouragement pour l'Industrie Nationale, 31 January, 1903, p. 89.)

From the knowledge acquired of the effects of sea-water upon mortars, it is evident that the extent of their porosity greatly influences the rapidity with which they are attacked. A mortar which is very permeable is exposed to disintegrating influences throughout its entire structure, while more compact specimens yield much more slowly to this kind of action. The Author discusses various methods in which different samples have been tested mainly by filtration, but he states that the experiments made in the laboratory frequently vary widely from the results obtained in actual practice. Certain inherent drawbacks in the case of tests made by means of filtration or aspiration are explained, and the methods by which they may be overcome are described. In lieu of filtration, he employed simple immersion tests, in order to estimate the degree of permeability by means of diffusion. The blocks of mortar were plunged into saline solutions for a given time, but these solutions were impregnated with certain reagents which would immediately reveal their presence in the interior of the sample under test when subjected to appropriate treatment. In this way it became possible, when the test-pieces were fractured and submitted to the action of the requisite reagent, to obtain a definite coloration of that part of the briquette which had been permeated by the test solution. Certain of the precautions needed for this procedure are pointed out, and the Author recommends the use of ferro-cyanide of potassium, which, when precipitated by a solution of ferric chloride in dilute hydrochloric acid, produces in those parts of the sample which have been penetrated a very intense prussian blue. This precipitate is, however, speedily acted upon by the lime, and fades away in about a quarter of an hour. A series of photographs of fractured samples are given, and tests are recorded of a number of different qualities of cement, some of which proved absolutely impermeable.

G. R. R.

The Portland-Cement Industry. E. Candlot.

(Bulletin de la Société d'Encouragement pour l'Industrie Nationale, 30 November, 1902, p. 589.)

It is insisted by the Author that Portland cement is a true chemical product, prepared by means of well-defined formulas. Its essential constituents are lime, silica and alumina, but accessory to these are oxide of iron, magnesia, sulphate of lime and sometimes potash and soda, titanic acid and manganese. The chemical changes which take place during the manufacture are briefly as

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follows:—At a temperature of about 1,000° C. in the kiln, after the carbonate of lime has become decomposed, the silica and the alumina react upon the free lime and enter into combination with it to form silicates and aluminates of lime. This action, which involves incipient fusion of the mass, is completed at a temperature of 1,500° to 1,600°, when the silica and alumina present will have each of them combined with three equivalents of lime. The finely powdered clinker, the Portland cement, on treatment with water acquires its initial set when the aluminate of lime crystallises on simple hydration, which may take place either rapidly or slowly, in accordance with various circumstances which favour or which interfere with this action. Then the tri-calcic silicate is decomposed by the water and parts with two equivalents of lime, which give rise to the crystals of hydrate of lime conspicuous in all cement mortars; finally, the mono-calcic silicate crystallises, and by its abundance and tardy formation effects the gradual induration of the cement.

The Author deals with the various stages of the manufacture, the preparation of the raw materials, the use of the wash-mill and the principal appliances for drying the slurry. Illustrations are given of the machinery and plant and sections of the Hoffmann, Dietzsch, Timm, Hauenschild and other kilns, also of the recent types of rotatory kilns. The question of grinding is discussed, both in ball- and tube-mills, and, in conclusion, comparative diagramatic sections are given of different factories, working on the wet system and on the dry system, with old-fashioned and with modern appliances, together with a plan of an American cement factory, with an output of 3,000 barrels of cement per diem. The statistics of the world's make of Portland cement for the year 1900 led the Author to conclude that the present annual total reaches from 7 million to 8 million of tons.

G. R. R.

The Conversion of Blast-furnace Slag into Iron-Portland Cement. JANTZEN.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, Feb. 1903, pp. 19–52.)

So far back as 1862 the hydraulic properties of granulated blast-furnace slag were observed, and experiments were conducted upon lime and trass mortars, with and without the addition of granulated and fine-ground slag, and in 1865 artificial stone blocks were manufactured in this way, of a mixture of slag with about 10 per cent. of burned and slaked lime subjected to pressure, an industry which has become very active in certain localities. Analyses of blast-furnace slag and of Portland cement show that the chief difference consists in the higher proportion of lime in the latter, and it seems only natural to suppose that, provided the

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right amount of lime be added to the slag, it will be converted into good cement. This may be done in three ways: 1. The slag may be enriched by the addition of lime in the blast-furnace; 2. the slag may be used, not as a raw material, but as an addition to the cement; 3. the slag may be used as one of the raw materials and combined with the proper proportion of lime in the ordinary process of manufacturing Portland cement.

The first method cannot be used in the ordinary process of iron manufacture, because the temperature is not high enough, but experiments are in progress to determine whether a suitable slag cannot be prepared in this way, when the production of iron is not the primary object. The second method has long been in successful commercial operation, and the Author quotes Dr. Michaelis and Prof. Tetmajer to support his view that Portland cement may be materially improved by the addition of slag and other natural and artificial silicates. The third method has now reached an annual output of about $1\frac{3}{4}$ million barrels of 170 kilograms weight, employing a capital estimated at 15 million marks. This cement was at first sold as Portland cement, because it satisfies all the conditions of Portland cement; but to distinguish the one from the other, the name iron-Portland cement has been adopted. The raw materials, granulated blast-furnace slag and coarse limestone, are brought to the cement works by a wire-rope conveyor. The limestone is passed through a stone-crusher and afterwards ground fine. The granulated slag, which contains from 20 per cent. to 30 per cent. of water, is dried almost at a red-heat in drums, and then cooled, also in drums, to the air temperature. Any particles of iron are then separated by means of an electro-magnetic apparatus; the slag and lime are intimately mixed by mechanical means, moistened, and compressed into blocks. These blocks are burned to clinker in ovens, and then ground up fine. The "Buderusschen" cement works can in this way produce, with a day and night shift, 180 tons of granulated slag, with an expenditure of 600 effective horse-power.

This cement not only satisfies the standard requirements for Portland cement in respect to time of hardening, but exceeds them as regards constancy of volume, fineness, and tensile and compressive strength. The standard test of strength for Portland cement is that with three parts by weight of sand to one of cement the briquettes, hardened under water, shall give a minimum tensile strength of 16 kilograms/square centimetre (225 lbs./square inch) and a compressive strength of 160 kilograms/square centimetre (2,250 lbs./square inch). An average of tests made from the iron-Portland cement, purchased in the ordinary course of trade, without the knowledge of the makers, and tested by independent experts, gave the accompanying figures on page 391.

The Author quotes further experiments to show that this cement also excels in the property of increasing its strength with time.

Fine ground slag mixed with caustic lye to a paste and poured

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Fineness.		Constancy of Volume.						
Residue upon		28 Days in Water.	Heat Test.	Setting Test.	Strength after 28 Days. 3 Sand to 1 Cement.			
					Tension. Kilo/sq. cm.		Compression. Kilo/sq. cm.	
900 Mesh.	5,000 Mesh.				Water.	Air.	Water.	Air.
Per Cent.	Per Cent.							
0·91	9·23	All the specimens passed these three tests successfully.			22·53	27·56	224·69	234·43

into moulds gave a tensile strength of 20·5 kilograms/centimetre (285 lbs./square inch) after 35 days, which explains the fact that bricks can be made of blast-furnace slag alone.

The Author quotes experiments to show the beneficial effects of adding the slag to neat cement, and contends that the present restrictions placed upon the sale of Portland cement are injurious to the development of the industry and the improvement of its manufacture.

E. H. S.

The Tensile Strength and Deflection of Ferro-concrete Constructions. F. Schule.

(Schweizerische Bauzeitung, vol. xl., 1902, pp. 237 *et seq.* Figs.)

The Author, who is a Professor at the Zurich Polytechnic, observes that no innovation in building construction has raised so many complex problems as the use of ferro-concrete construction, and he mentions the labours of Mr. Considère, who has studied the theory of the subject. The present article deals with a series of experiments which were made in the federal laboratory for the testing of materials at Zurich in 1902. Some of the beams tested were of concrete and some of ferro-concrete, and the dimensions of the specimens were recommended by Prof. Tetmajer with a view to tests upon the Amsler-Laffon press, and for purpose of comparison with beams of natural stone. The concrete beams were 67 inches long, of rectangular section, 7·9 inches wide by 11·8 inches high; each was laid upon a pair of steel supports, 1·97 inch diameter, spaced 59 inches centre to centre, and the beam was tested by a concentrated load applied at the centre.

Six beams were tested, three made of concrete only, and three of ferro-concrete of the Hennebique system. After rupture, cubes were cut out of the beams near the fractured ends, and these cubes were subjected to compression tests.

A very detailed description is given of the minute care taken in the tests, and the results are tabulated; the maximum load carried

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by the concrete beam was 3·06 tons, and by the ferro-concrete beam 15·6 tons, before fracture.

Very careful observations were made for deflection with a Bauschinger mirror instrument, and a large number of graphic curves are given in the original. With the ferro-concrete beams the first cracks in the concrete appeared with a load of 5·5 tons, and with a load of 7·5 to 8 tons the limit of elasticity of the steel wires seemed to be passed.

The Author concludes that exact calculations, such as are made upon steel joists, cannot be made upon mixed structures of concrete and steel, but the results obtained are of considerable value, and further tests are to be made.

E. R. D.

Dry-Rot.[1] MALENKOVIC.

(Mitt. über Gegenstände des Artillerie- und Genie-weseus, 1902, p. 1095.)

In this Paper the Author discusses the origin and predisposing causes of dry-rot in timber, and appends a list of the principal German authorities on the subject. Dealing with the inception of dry-rot the Author holds that this fungus (*Merulius lacrymans*) may propagate itself either by mycelia or by spores. In opposition to the opinion of some mycologists he contends that propagation by spores is undoubtedly the principal method by which dry-rot extends its evil influence, for whilst the mycelia are extremely sensitive and perish at once when the environment is not exactly suitable to their growth, the spores on the contrary are insensible to cold, light, air-currents, and the absence of moisture, and are distributed by wind, animals, and other agents in all directions. In order that the mycelium should exist at all in the living wood, it would first be necessary to destroy the sap cells, and since the fungus does not appear to possess the power to effect this, it cannot grow in the interior of the tree; nor can it exist on the exterior, being extremely sensitive to currents of air. For these reasons, and from his own researches, the Author attributes the existence of a contrary opinion to difficulty of identification. Infected wood, which has been exposed for two or three weeks to air-currents and protected from rain, will contain no trace of the living mycelium, and the Author quotes an experiment in which, after the wood had been replaced in its former position, no trace of the living fungus could be detected after nine months. The presence of alkalies acts as an incentive to the development of dry-rot. The calcium bi-carbonate $CaH_2(CO_3)_2$ arising from the hydrate of lime in mortar is probably the chief agent in the development of

[1] Minutes of Proceedings Inst. C.E., vol. lxxx., 419; vol. lxxxvi., 381, 384.

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the spores, and hence it is found, almost without exception, that the wood nearest to the walls of buildings is first attacked. The Author proceeds to describe the means to be employed for producing the fungus artificially and subjecting it to experiment.

The only precautions which the Author suggests to prevent dry-rot, are the well-known ones of giving free access to the air and avoiding contact between the wood and brickwork. Where this is not practicable recourse may be had to antiseptics.[1]

E. H. S.

Hydraulic Laboratory of the Technical High School at Karlsruhe. THEODOR REHBOCK.

(Zeitschrift für Bauwesen, 1903, pp. 103–135.)

The object of this laboratory is the study, on a reduced scale, of the flow of water in rivers, the action of the current on a movable bed and on the banks, the effect of piers, piles, etc., upon the flow, and the determination of coefficients, etc., required in hydraulic engineering. The design is similar to that of the laboratory constructed at Dresden in 1898, a description of which is given in the "Zeitschrift für Bauwesen," 1900, p. 343, etc. The building is rectangular, 25·71 metres × 7·44 metres × 2·90 metres high (84 feet × 24½ feet × 9½ feet) and is well lit. The essential parts are: 1. The channel; 2. The arrangements for introduction of water and sand; 3. The apparatus for measuring the water and sand in suspension, the form of the water-surface and of the bed.

The channel is accessible from both sides. It is 2 metres (6 feet 6 inches) wide, so that any point can be reached from one side or the other. In some cases a greater width would be better, in order to get sharper bends. The depth of the channel is 40 centimetres (15¾ inches), but this might be reduced with advantage to 30 centimetres (1 foot); 10 centimetres (4 inches) of sand, and 10 centimetres (4 inches) of water have been found sufficient for almost all experiments. The upper end can be raised from the horizontal to a height of 40 centimetres (15¾ inches) and it then reaches 140 centimetres (4 feet 7 inches) from the floor. The channel is constructed of two plate girders with cross-girders 40 centimetres below the upper edge, and 1 metre (3 feet 3 inches) apart. These cross-girders carry the floor, which consists of plates 5 millimetres ($\frac{3}{16}$ inch) thick. The main girders are 90 centimetres (3 feet) high, of 7 millimetres ($\frac{5}{16}$ inch) plate. The cross-girders, however, are found to bend excessively under heavy loads, and it is therefore recommended that they should be deeper. The upper end is supported from hangers, and is raised and lowered by screws which turn upon ball-bearings. These

[1] Mitt. über Gegenstände des Artillerie- und Genie-wesens, 1902, p. 1065.

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screws require 2,000 turns to raise or lower the apparatus through 40 centimetres. This takes about 1 hour by hand, and it is proposed to have an electric motor of 0·37 HP. The inclination is read off on a scale. The deflection of the main girders was also excessive, and several methods of diminishing it are suggested, such as shortening the unsupported length, increasing the moment of inertia of the cross-section, etc. The water used enters through a trough 1·5 metres (5 feet) wide, leading from a reservoir in which the water from the numerous inlet-pipes is brought to rest by means of baffle plates. The quantity of water being too great for the town supply it is necessary to use the same water over and over again. This is done by the use of a circulating pump whose capacity is 60 litres (13·2 gallons) per second, driven by a continuous-current motor which, at 110 volts and 926 revolutions, gives 13 HP. The upper basin is 2·7 × 1·75 × 1·25 metre (8¾ feet × 5¾ feet × 4⅛ feet) deep. It holds 5·9 cubic metres and is filled from the town mains. For an experiment 9 cubic metres (1980 gallons) of water are required. The quantity flowing is measured by noting the head in the upper basin with a float and scale and comparing it with the water-level in the exit pipe. The corresponding discharge is then obtained from Tables previously prepared by actual measurement.

Sand is supplied from two hoppers hung from the roof. These are set swinging at right angles to the axis of the channel, and the flow of sand can be adjusted. The quantity carried away by the water in suspension in a given time is determined by collecting the sand, drying it, and weighing.

The measurement of the slope of the water-surface is made by means of an apparatus described in the "Zeitschrift," 1900, p. 350.

The form of the bed and banks is determined by means of a level, or by taking plaster casts.

The sand is washed and passed through sieves. It is of different degrees of fineness, and is stored in four concrete hoppers, from which it slides down by gravity into a receptacle; it is then raised by a small sand elevator electrically driven, and delivered on to the floor of the channel. To trace the distribution of the sand coloured sand is used, either natural or artificially prepared.

For protecting the banks and for forming model obstructions in the stream small bags filled with leaden shot are used. There are 5,100 of these, 4 × 8 centimetres, 4 × 6 centimetres, and 4 × 4 centimetres (1·6 inch × 3·2 inches, 1·6 inch × 2·4 inches, 1·6 inch × 1·6 inch), and 1 centimetre (0·4 inch) thick, which are kept on shelves along the sides. The bags are protected from the lead salts by impregnating them with ammoniacal copper-oxide; or, if this is found to be insufficient, it is proposed to use galvanized iron shot.

The cost of a special building, well heated and illuminated, and having a covered area of about 250 square metres (300 square yards), is estimated at from 20,000 marks to 25,000 marks (£1,000 to £1,250), apart from the cost of ground. The equipment of such

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a laboratory as the one described is estimated to cost from 15,000 marks to 16,000 marks (£750 to £800), which must be increased to 18,000 marks or 20,000 marks (£900 or £1,000) if no electrical current is available, so that special arrangements have to be made for generating it.

The description is thoroughly illustrated, and suggestions and plans for an improved laboratory on the same lines are also added.

E. H. S.

Construction of Thermometers. STEINLE.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, Feb. 1902, p. 52, &c.)

The glass thermometer, on account of its liability to fracture and the indistinctness of its readings, no longer satisfies commercial requirements. At the same time, thermometers which depend on the difference of expansibility of various metals are subject to unavoidable errors; so that the expansion of a fluid, and preferably mercury, still remains the best general means of measuring temperature. The thermometer here described affords almost any range between $-20°$ C. and $+500°$ C.; the reading is easily observed, and indeed at a greater or less distance from the source of heat, according to convenience. It consists essentially of a steel reservoir containing mercury, to which is connected a flattened spiral spring having a capillary bore. The mercury is under a pressure of about 45 atmospheres, and cannot therefore boil under 500° C. Temperatures up to 600° C. can be measured, but after that the mercury is forced through the pores of the metal, and for this reason the danger of an explosion is almost out of the question. The temperature is measured by the change of volume of the mercury. The thermometer is tested at the higher temperatures, until it returns correctly to its zero, and an adjustment is provided for the index. The spiral spring, whilst it contains only an extremely small quantity of mercury, is sufficiently strong to actuate the pointer and registering mechanism, and converts the expansion of the mercury directly into rotation, which is registered by a pointer on a dial, like a common steam-gauge. The rod which connects the capillary spring with the pointer mechanism is free to move vertically without affecting the pointer, so that only the rotation of the spring is registered, and the reading is therefore independent of the length of the connections. For temperatures above 100° C. the spring is removed to a sufficient distance from the mercury reservoir that it shall be unaffected by the source of heat. Also, the dial can be set up in any convenient position for observation, flexible thermometers having been made on this principle up to 33 metres long (108 feet 4 inches).

The error due to a long capillary tube increases as the volume of

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the mercury reservoir diminishes, and consequently it is best to graduate the thermometers for the special range of temperature which they will be required to register, so that the intervals may be larger and the capacity of the reservoir greater.

E. H. S.

Alternate-Current Electrolysis. E. WILSON.

(Electrician, vol. xlviii. pp. 1025–1026, April 18, 1902.)

As alternate currents are employed in rail-returns for electric traction, the investigation of the electrolytic effects of alternate currents has become of practical importance, especially in the case of lead, which is extensively employed in underground work. An alternating current of density 0·024 amperes per square centimetre and frequency 89 per second was passed for seven hours between two parallel plates of commercial lead 0·317 apart, immersed in dilute sulphuric acid. At the beginning of the experiment, while the plates were still bright, a curve of the potential difference was obtained between one of the plates and an exploring platinum electrode introduced half-way between the plates; simultaneously a curve of current was obtained by finding the instantaneous value of the potential difference between the ends of a non-inductive resistance placed in the circuit. These observations were repeated at the end of the experiment, using the same frequency, and the results plotted as a cyclical curve, the area of the curve representing the work spent upon electrolytic hysteresis, as, with the current densities employed, the potential difference due to conductivity of the electrolyte is negligible. A curve of similar form was obtained for frequency 23·3 per second, and current density 0·007 amperes per square centimetre. The ratio of the area of the first curve to that of the second was 0·854 to 1. A considerable amount of $PbSO_4$ was formed, so that the experiments were repeated with pure lead plates, using a current of 0·024 amperes per square centimetre, and frequencies 92·5 and 21·5. The diminution in weight was nearly twice as great at the lower frequency as it was at the higher, and the cyclical curves were of the same form, and the ratio of their area 0·22 to 1. This shows that frequency plays an important part in the reaction; the effect is entirely due to the current, as plates immersed in the same electrolyte when no current is passing are only slightly discoloured. Experiments were also conducted with aluminium plates in a solution of alum. The effect of the film of basic aluminium sulphate formed is very marked with alternating currents. Two aluminium and two iron plates of equal areas and the same distance apart were placed in alum solutions of equal strengths, with a current of frequency 17 and density 0·0169 ampere per

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square centimetre; the maximum volts between the aluminium plates were 46, and between the iron plates 1·3.

A table of results is given :—

Data from Curves.	Commercial Lead.	Pure Lead.	Pure Lead.
Frequency in periods per second .	89·0	92·5	21·5
(1) At beginning of experiment:			
Maximum coulombs	0·0095	0·0094	0·0394
Energy dissipated per plate per period in joules	0·0226	0·021	0·1122
Average watts per plate . . .	2·13	1·94	2·42
(2) At end of experiment:			
Maximum coulombs	0·00947	0·0090	0·0406
Energy dissipated per plate per period in joules	0·0226	0·0316	0·1245
Average watts per plate . . .	2·13	2·92	2·68

W. C. B.

Pulverized Fuel for Power Plants. F. G. Gasche.

(Railroad Gazette, vol. xxxiv. pp. 466–467, June 20, 1902.)

The author maintains that only the cost of pulverising has hitherto hindered the economical use of powdered fuel, but that modern methods have greatly improved that aspect of the industry. Results of comparative tests with the same coal used in hand-fired and dust-fired boiler furnaces are given in tables, and show 71·8 per cent. efficiency of boiler and furnace with dust fuel and 52·2 per cent. for hand-firing.

The saving in fuel required to evaporate 5,175 lbs. of water from and at 212° F. was 10·75 per cent. by the dust-fuel method.

F. J. R.

Stability of Automobiles on Curves. A. Petot.

(Comptes Rendus, vol. cxxxiv. pp. 765–768, April 7, 1902.)

The paper contains a simple mathematical consideration, with a view to the guidance of experimental work, of side-slip and the tendency to upset when an automobile is turning, or following a curved route. When travelling in a circle there will be more tendency to side-slip on the part of the front wheels with increasing speed, and on the part of the rear wheels with diminishing speed. To prevent the latter effect when braking, the brake must therefore be gradually applied. When the radius of the circle is decreasing—in other words, when the curvature of

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the path is increasing—the tendency of the front wheels to side-slip is accentuated, and that of the rear wheels when the curvature decreases, as, for example, in passing from a curve to the straight. The formulas show clearly that, in order to avoid side-slip, the transition from one curve to another of different curvature must never be made abruptly, and the author believes that attempting to do this has been the true cause of several serious accidents which have been attributed to defects in the steering gear. A point which should be noted by designers and builders of motor cars is that the tendency to side-slip can be reduced by so distributing the weight of the car and its contents as to make the swing radius about the vertical through the centre of gravity as small as possible [that is by a concentration of the weight as near as possible to this line], and it is also of advantage that the weight should be symmetrically disposed with regard to it.

G. W. DE T.

The Zossen Marienfelde Polyphase Railway Trials.

(Engineering, vol. lxxiii. pp. 547–548, April 25, 1902.)

In the trials hitherto made special attention was given to the following points: (1) Starting and braking at speeds up to 100 kilometres (62 miles); (2) running at uniform speeds up to 100 kilometres; (3) propulsion at uniform speeds up to 130 kilometres (81 miles); (4) propulsion by high-pressure currents at speeds above 130 kilometres. The rails on this line weigh only 34·4 kilograms per metre (67·5 lbs. per yard), and rest partly on wooden and partly on iron sleepers. As expected, the defects in the track became manifest at high speeds. Up to 100 kilometres no concussions were noticed in the carriages, nor were distortions observed. After 140 kilometres (87) miles there was slight rolling, owing to the lightness of the permanent way. The three-axled bogies were quite satisfactory, giving noiseless motion without any jolting at the rail joints. The experiments would tend to show that rails weighing 42 kilograms per metre (84·5 lbs. per yard) would be quite heavy enough for speeds up to 160 kilometres (100 miles). The quiet motion was doubtless largely due to the complete balancing of the car. There was very little sparking, even at the highest speeds, at the contact bows, which exerted a pressure of 4–6 kilograms (9–13 lbs.) against the trolley wires, and when observed, it could be traced to slight defects in details. Lateral oscillations in the car were only observed at speeds below 60 miles. The heating of the transformers on the car did not exceed 35° C. At the lower speeds employed in the earlier trials, the trolley-line pressures varied from 6,000 to 8,000 volts, with a periodicity of 25–30. For the higher speeds the pressure was raised to 10,000 volts with a periodicity of 36, and temporarily to 13,500 volts with a periodicity of 48. At the highest speeds,

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between 99 and 100 miles an hour, the rails began to yield, both horizontally and vertically, so that the tests had to be interrupted, pending the strengthening of the permanent way. With regard to braking, the conclusions arrived at were that further and more efficient means should be devised. Braking by current reversal is not to be recommended, as it endangers the motors. The power consumption, depending on the speed and the starting acceleration, varied between 400 kilowatts and 700 kilowatts. With a power consumption of 184 kilowatts a uniform speed of 90 kilometres (56) miles could be maintained, and 140 kilometres (87 miles) with 520 kilowatts; so that about 1,000 HP. would be required for a speed of 200 kilometres (125 miles). The air-resistance experiments showed that the rise in the air pressure did not extend beyond a distance of 3·3 metres in front of the car. The rounding of the sides and roof was found to be of a very important feature. There was practically no increase of pressure on the rear portion of the car, nor was any noteworthy suction effect observed in its wake.

G. W. DE T.

High-Speed Electric Railways. G. W. MEYER.

(Zeitschr. Elektrotechn., Wien, vol. xx. pp. 169–174, April 6, 1902.)

The Author commences by discussing certain formulas for the determination of the horse-power required to drive a train at certain speeds, taking into account the air resistance. He also refers to the work already done by Reichel, Kapp, and others on this subject. He then proceeds to consider the system most suitable for main lines, and thinks that this must obviously be the polyphase system without any admixture of direct current or rotary convertors. Two methods are therefore possible, viz., system A, in which the high-tension current is transformed in substations, placed at intervals along the line, alternate current being then supplied at lower pressure to the locomotives; and system B, in which the high-tension current is transformed by transformers carried by the train themselves. The trains are supposed to consist of single cars, holding ninety persons; on system A, the loaded cars would weigh 110 tons, and on system B, 145 tons. The speed is taken as being 180 kilometres per hour with a maximum speed of 200 kilometres. By the application of the formulas, a train on system A is found to require 1,800-HP., or 1,420 kilowatts, allowing for losses in the motors; on system B, it would require 2,000 kilowatts, allowing for losses in motors and transformers. The former therefore requires four 500-HP. motors, and the latter four 600-HP. A further allowance must be made in favour of system A in consequence of the fact that much higher transmission pressures are possible in this case; current transmitted at the highest pressures cannot conveniently be dealt with

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on the train itself, whereas a pressure of 55,000 volts presents no difficulties in substations. The Author then considers the case of running half-hourly trains between New York and Chicago, and calculates that the amount of power required under the two systems would be in the proportion of 10 to 13. In consequence of the higher pressures used in system A, one or at the most two central stations should be possible; in the case of the New York and Chicago line, the whole could be supplied from Niagara, and each substation would supply 40 kilometres of the line at 6,000 volts. Supposing in the case of B that 20,000 volts was a possible pressure, the Chicago and New York line would require ten central stations, and each of these would supply a length of about 160 kilometres of the line.

W. H. S.

Competition of Steam and Electric Railways. C. H. Davis.

(Street Railway Journal, vol. xix. pp. 310–314, April, 1902. Paper read before the Canadian Society of Civil Engineers.)

The paper discusses in detail, with numerous curves and Tables, the financial effects of the competition of electric street railways, on various steam railroads in the United States, during the period from 1889 to 1898. The conclusion arrived at is that where steam railroads have been seriously affected by the competition it is almost invariably due to their routes being ill-adapted for local traffic, and that the general effect of the development of the electric street railways is to largely develop local passenger traffic, and, by good management on the part of the steam railways, may be made to act as feeders to them, and therefore increase, instead of diminishing their profits.

G. W. de T.

Electric Railways. L. Gerard.

(Soc. Belge Élect., Bull. 19, pp. 183–281, April, 1902.)

This is a critical discussion of the various systems of electric traction, with illustrations drawn from numerous important systems in use in Europe and America. The relative advantages of electricity and steam are specially discussed, the preference being given to the former, mainly on account of the high efficiency attainable and the reduction of dead weight to a minimum. Accumulator attraction is at a disadvantage in both these points, and is only to be contemplated under quiet special conditions.

G. W. de T.

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The Diatto Surface-Contact System. C. H. Julius.

(Assoc. Ing. Él. Liége, Bull. 2, pp. 63–126, January, 1902.)

This is a very complete treatise on the system, with a discussion of its development and working in Paris, a comparison of its capital and maintenance costs with those of the trolley system, and a full consideration of the various imperfections which have been discovered in practice and the methods of eliminating them. The Author's conclusion is that the system is one of great value for use in places where trolley lines are excluded, and that the difficulties which have hitherto arisen are all of a kind that can be overcome in the light of experience which has been obtained in the use of the system in Paris. The paper is illustrated by numerous sectional drawings.

G. W. de T.

The Transition Spiral. W. M. Torrance.

(West. Soc. Engin., Journ. 7, pp. 145–163; Discussion, pp. 163–216, April, 1902.)

The Author contends that in order to obtain the best possible riding quality for fast trains resort should be had to the use of transition spirals. The correct method of obtaining super-elevation at the end of a curve is to insert between the tangent and the circular curve a transition spiral in which the curvature increases from zero at its tangent end directly with the distance from the end to the curvature of the regular circular curve at its other end. The centrifugal force which renders super-elevation necessary is directly proportional to the curvature at any point. If super elevation is introduced into the line on the spiral, in exact proportion to the curvature in it, every condition for an easy riding is satisfied. The Author does not agree that financially, and from an engineering standpoint, it is difficult to maintain a spiralled curve, as, properly constructed, it will practically maintain itself, whereas, if there is no spiral, the line is certain to require constant attention on the part of the trackmen. The Author supports this by contending that there are very few main-line curves which the permanent-way men have not found necessary to "ease off" if the engineer has not come to their aid by giving them spirals. Other salient points of the paper are: (*a*) That it is always possible on an old track to add spirals to the curves by throwing them out so little as to be quite inexpensive; this will be especially true if the spirals are added while other work, such as extensive ballasting or doubling the line, is being done. (*b*) To see that after the spiralled centre line is staked out and the track is being made to conform it, for line, the ends of the super-elevation run off are made by the permanent-way men to conform exactly

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with the ends of the spiral, and that the change from zero at one end to the full super-elevation is obtained proportionately to the distance from the zero end. The discussion brought into prominence the fact that most practical engineers in charge of maintenance declared in favour of spiralling railway curves, although views antagonistic to the principle were freely expressed. The most important were that spirals do not help a moving train to run in a circular direction, as the motion is as much "on tangent" when it has reached a heavy curve direct from tangent as when supposed to be coddled into curvature by a spiral. Further, that lateral elevation is dependent on curvature and speed, and that the road most perfectly spiralled for one degree of speed is a bad misfit for all other speeds. The latter objection, however, applies to any curve having lateral elevation, whether spiralled or not. The Paper describes various methods for spiralling curves on maintenance work, and is accompanied by useful diagrams and Tables.

C. E. A.

Electric Locomotive for Rack and Adhesion Railway. M. Gaze.

(Zeitschr. Vereines Deutsch. Ing., vol. xlvi. pp. 600–695, April 26, 1902.)

The Author describes a short line which has been constructed for the purposes of a sugar refinery on the Elbe, the steepest incline on which is one of 15 per cent. It is worked partly by adhesion and partly by the Abt rack. The article deals mainly with the mechanical construction of the locomotive and track, and specially notices such details as are connected with the passage from the rack-driven part of the line to the other portion.

W. H. S.

Tractive Effort and Power of Tramway Motors. H. C. King.

(Tram. Rly. World, vol. xi. pp. 383–386, June, 1902.)

This paper discusses the points to be taken into consideration in the selection of tramway motors. For suburban work high speeds, for city work high accelerations are required—higher in proportion to the density of the traffic. Acceleration should not be uniform, but small at first, say 0·5 ft./sec.2 increasing to as high a rate as possible; the mean acceleration can thus reach a high value without discomfort to the passengers. Attention should be paid to the paring of motors so that when coupled in series each may take its proper share of load without differing in speed from the other. A convenient way of making a pairing test is described. A diagram is given showing graphically (1) tractive effort as a function of weight of car and gradient; (2) the same as a function

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of weight of car and acceleration; (3) B.HP. as a function of tractive effort and speed, and by numerical examples the diagram is explained. B. P. S.

Telephone Conduits. RÜHL.

(Archiv Post Tele., vol. vii. pp. 213–227, April, 1902.)

This is an account of the methods adopted in Berlin and other German towns for putting in telephone cables under streets, with special reference to economy, durability, convenience of drawing in or out, and provision for space for subsequent increase of business. As regards materials, it is shown that cast-iron compares very badly with cement. References are given to descriptive accounts of the various systems, and dimensions of some of the more important conduits are marked on the figures. Details of comparative costs of some of the Berlin systems are quoted, and other particulars relating to the weight of the blocks, tubes, and plates, together with notes on the comparative rates of construction, are added.

R. A.

Transit Theodolite for Mining Engineers. H. D. HOSKOLD.

(Inst. Mining Engin., Trans., vol. xxii. pp. 536–557; Discussion, pp. 557–566, 1902.)

A detailed description is given, with drawings and illustrations, of a theodolite to be used for connecting underground workings to the surface, *vice versâ*, and for general surveying. The lower part of the telescope stand consists of a hollow cylinder, so that a sight can be taken in the direction of the nadir, and so down a shaft by means of a side eye-piece. The method of using the instrument in shaft, and the necessary adjustments, are fully described. The discussion after the Paper turned chiefly on the disturbance of plumb-lines in long shafts by air-currents, and the Author claimed that greater accuracy was to be obtained by using his instrument or an astronomical one than by the use of plumb-lines.

G. E. A.

Harmet Process for the Production of Steel Direct from the Ore.

(Electro-Chemist, vol. ii. pp. 93–95, May, 1902.)

In a Paper read before the Société de l'Industrie Minérale de Saint-Etienne, on 5 April, 1902, Harmet deals with the reduction of iron ores in a furnace in which the whole of the necessary heat is electrically generated, the only quantity of coke introduced

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being that strictly necessary for production of the reducing gases. Ore and flux are fed into a drying or calcining kiln to be freed from water, carbon dioxide and other volatile materials, and heated to redness by means of blow-pipes. The burning gases from the latter pass through the whole mass before escaping to the atmosphere, the red-hot material being forced through low lateral passages by means of a piston into hoppers, and thence to the reducing furnace proper. The coke is heated before being fed into the furnace, the hot mixture of coke, ore and flux slowly descending into a shaft. To ensure complete reduction before the mixture reaches the hearth, the gases generated by the combustion of the coke are drawn out at the head of the furnace, and forced by a blowing machine through a tube communicating with the base of the furnace, where carbon dioxide, in presence of red-hot coke, is reduced to the monoxide, which, besides serving the part of a powerful reducing agent, also acts as a vehicle for the heat electrically produced on the hearth, and not absorbed by the fusion of the iron. Tables are given showing thermic equivalents of two methods of treatment of a given mixture, as well as sketches of the furnace details.

O. J. S.

The Parallel Operation of Alternators.

H. E. LONGWELL.

(Street Rly. Rev., vol. xii. pp. 358–361, June, 1902. Paper read before the Engine Builders' Association of the United States at the annual meeting held in Pittsburg, Pa., May 22 and 23, 1902.)

In this Paper the Author starts with the assumption that there will always be a certain amount of irregularity in the engine speed, both cyclical and in successive revolutions, which will necessarily produce some transfer of energy from one alternator to another, and that it is therefore useless in discussing the question of parallel running to assume perfectly uniform speed. The cross currents can never be entirely eliminated; all that can be done is to reduce them as much as possible. It is incorrect to say that bad parallel running is ever due to hunting, or otherwise faulty governors, though these may aggravate the evil; as a fact, the most perfect governor from an engine-builder's point of view is the worst for parallel operation, since the duty imposed on it under these conditions is directly opposed to its natural function. The leading machine tends to take more of the load, and ought, therefore, for equilibrium to be restored, to have its steam-supply decreased, but the natural tendency of the governor is precisely the opposite. Hence it must be rendered sluggish by dash-pots and similar devices. Referring to the uniformity of angular speed, which is usually considered essential, the Author criticizes the Westinghouse specification on the ground that it is unreasonable

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to demand the same limit for angular variation in all cases, when generators vary so greatly in their electrical characteristics. The short-circuit current of some generators is as low as 2½ times the full-load current, while that of others may be 6 times the full-load current. With the same maximum fly-wheel displacement, the cross-currents in the latter case will be much greater than in the former; hence either the allowable displacement is too small in the former case, or it is too much in the latter. The question of synchronizing force is discussed, the assertion being made that in every practical case its effect is to increase the irregularity of the angular speed of the engine instead of diminishing it. An instance of this seeming paradox is cited, where by decreasing the terminal pressure of a two-phase alternator by weakening the parallel running was greatly improved, so that both phases could be coupled in parallel, whereas with normal excitation it was impossible to parallel on more than one phase. By means of a diagram this result is shown to be what was theoretically to be expected. Starting with the curve of crank effort, approximately sinoidal, a second curve is obtained by integration, the ordinates of which represent the velocity of the crank-pin above and below the mean velocity. This velocity curve is clearly also sinoidal, lagging 90° behind the curve of crank effort. Integrating the velocity curve, a third curve is obtained, the ordinates of which represent displacement in front of or behind the position corresponding to uniform velocity; this curve is also sinoidal, and lags 90° behind the velocity curve, and therefore 180° behind the curve of crank effort. Thus, when this latter is at a maximum and the surplus energy is accelerating the rotating masses, these are always at their maximum displacement behind the position corresponding to uniform angular speed, and *vice versâ*. But since the synchronizing force due to cross currents is proportional to the displacement, and tends to accelerate the rotating masses when these are behind the mean position, and to retard them when they are in advance of it, it follows that the synchronizing force is acting in unison with the crank-pin effort, and hence tends to increase the displacement. The amount by which this is increased depends to a large extent on the natural oscillation period of the rotating masses. B. P. S.

Chenard-Walcker Motor Carriage.

(France Automobile, vol. vii. pp. 232–235, April 12, 1902.)

In this carriage, which is described in detail in the article, the main feature consists in the mounting of the motor and transmission gear symmetrically about the longitudinal vertical plane midway between the pairs of wheels, the object being to minimise the effects of vibration and to enable the working parts to be placed high above the ground so as to render them easy of access

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for examination or adjustment. The transmission shaft is divided into two parts, situated one above the other and connected by the change-speed gear, which is completely enclosed in an oil bath. This gearing is arranged for three forward speeds and one reverse speed, and is designed so as to minimise flexure of the shaft as much as possible in effecting the speed changes. The front portion of the transmission shaft is coupled to the motor fly-wheel by means of a spring friction clutch coupling, which may be disengaged by means of a foot lever. The rear part of the shaft is articulated and drives, through bevel gear, a live axle, supported above the rear axle, which is fixed. This live axle transmits power to the hubs of the rear wheels by means of spur gear. The article is illustrated by views of the various working parts of the vehicle.

J. G.

Ader Light Automobile. L. FOURNIER.

(Locomotion Automobile, vol. ix. pp. 230–233, April 10, 1902.)

This article deals with the 8-HP. type of Ader vehicle constructed by the Société Industrielle des Téléphones. The motor is of the four-cycle type, and has two cylinders arranged at an angle to each other, in a vertical plane. Power is transmitted from the motor through change speed and bevel gear to a countershaft, from which the rear axle is driven by means of a chain transmission—two brakes are fitted—one, a foot-operated brake, being applied to the rear axle and working on pulleys attached to the differential gear, and the other, a hand-operated brake, having action upon the front axle. The brake-controlling gear is arranged to that when the brakes are brought into action the supply of explosive charge to the motor cylinders is simultaneously reduced. The chief feature of note in this vehicle is the vaporiser, which is an adaptation of the old wick type hitherto little used. It consists of a chamber in which the oil supplied is maintained at a constant level by means of a float-controlled valve. A number of wicks dipping into the oil are suspended from the top of the chamber, which is removable, and carburation is effected by the aspiration of air through the wicks. The vapour formed is supplied to a mixing valve, where a further supply of air is added to form the explosive mixture for the motor cylinder. Lighting back from the cylinder through the mixing valve is prevented by means of wire-gauze screens placed across the outlet from the mixing valve. The discharge from the motor cylinders takes place through an exhaust silencer consisting of four concentric tubes enclosed in a chamber, the gases passing successively through the tubes before escaping to atmosphere. The article is accompanied by illustrations of the mechanism.

J. G.

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Daimler Cars.

(Automotor Journal, vol. vii. pp. 357–360, July 20, and pp. 384–387, August 2, 1902.)

A complete description is given of the "1902" types of cars manufactured by the English Daimler Motor Company. The chief types are a 9-HP. car with double-cylinder engine, and 12-HP. and 22-HP. cars with four-cylinder engines. The general arrangement of the mechanism is identical in all cases. The main frame, sprung from the axles on semi-elliptic springs, is constructed of wood reinforced with steel plates. A subsidiary frame of angle steel is hung from the main frame towards its front end, and carries the engine and friction clutch. The shaft carrying the male portion of the clutch is coupled to the lower shaft of the change-speed gear by an adjustable coupling, and motion is transmitted to the upper gear shaft by one of four sets of spur-wheels, which correspond to three forward speeds and one reverse speed. The differential cross-shaft, which is in front of the main portion of the gear-box, is driven by bevel gearing from the upper spur-wheel shaft. The final transmission is by independent chains to the rear road-wheels. The weight of the chains in the 9-HP. and 12-HP. cars is from 14 cwt. to 15 cwt., and about 22 cwt. in the 22-HP. car. In the 9-HP. engine the cylinders are 105 millimetres bore × 100 millimetres stroke, both pistons being coupled to a single crank-pin on a shaft in which the engine fly-wheels form the crank webs. The 12-HP. engine has cylinders 86 millimetres bore × 100 millimetres stroke, and the normal speed is 930 revolutions per minute; and the 22-HP. engine cylinders are 105 millimetres bore × 130 millimetres stroke, normal speed 720 revolutions per minute. Both these engines have external fly-wheels.

C. R. D'E.

Barton's Airship.

(Engineer, vol. xciii. p. 392, April 18, 1902.)

Its largest diameter is about two-fifths from the front end; it is 180 feet long and 41 feet diameter, capacity 156,000 cubic feet; this gives a lifting capacity of 10,080 lbs. The upper surface is enveloped in a chemise provided with cane stiffeners, from which the car is suspended. The ship is propelled by six two-bladed triple-fans. Each pair of fans will be driven by an oil-motor, exerting 45 B.HP. Mr. Alexander's experiments at Bath show that a thrust of 25 lbs. per B.HP. can be obtained. In this instance the thrust is taken as 20, giving a total of 2,700 lbs. for the six fans. There are three sets of aeroplanes, each set consisting of three, one over the other, each aeroplane having a rod in front for the pivot and a rod in the rear for raising and lowering the end by links. The deck remains horizontal by means of water-tanks at each end, each containing

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50 gallons of water, which is kept by means of a pump and connecting pipes, in a constant state of circulation. A pendulum-operated valve is arranged so that should one end of the deck drop, the pendulum shuts off the water from the lower end and pumps it to the upper tank till the level of the deck is restored.

	Lbs.
Envelope with chemise and attachments	1,900
Subsidiary balloon	140
Five men	800
Motor spirit 216 gallons	1,460
Six 17-foot fans	500
Three 45-B.HP. engines	1,150
Deck, superstructure, and aeroplanes	3,500
Instruments, goods, clothing, and sundries	150
Total	9,600

The area of the balloon is 1,320 square feet. According to Rouse and Smeaton, the air-resistance of a flat surface at 13 miles per hour is just under 1 lb. per square foot. Langley showed that this amount is excessive. The pressure is reduced if the object is in the form of a cone, and the resistance is variously given as from one-third to one-fifth of a flat surface. Therefore the resistance is under 700 lbs. The thrust available is 2,700 lbs., and a speed exceeding 20 miles per hour may be expected.

M. O'G.

Standardizing Electrical Machinery.

(Amer. Inst. Elect. Engin., Trans., vol. xix. pp. 705–721, May, 1902.)

This is a revision, "in view of such suggestions and extensions as experience and practice have since indicated to be desirable," of the 1897 report of the Standardization Committee. It opens with a number of preliminary definitions, and then proceeds to the consideration, in detail, of the methods to be adopted in specifying and measuring the efficiency of electrical apparatus and equipment, classified under the following sections: Commutating Machines, Synchronous Machines, Synchronous Commutating Machines, Rectifying Machines, Stationary Induction Apparatus, Rotary Induction Apparatus, Transmission Lines. The permissible limits of temperature rise are next considered, referred to the standard conditions of a room-temperature of 25° C., a barometric pressure at 760 millimetres, and normal conditions of ventilation—that is, the apparatus under test should neither be exposed to draught nor enclosed, except where expressly specified. The minimum temperature limits fixed are as follows: For the fields and armatures of commutating, rectifying and synchronous machines, 50° C., to be measured by resistance; for commutator and collector rings and brushes, 55° C., by thermometer; for the

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electric circuits of rotary induction machines, 50° C., by resistance; for squirrel-cage or short-circuited armatures, 55° C., by thermometer; for the electric circuits of continuous-service transformers and for reactors, induction, and magneto-regulators, 50° C., by resistance; for bearings, and for all parts not specified, 40° C., by thermometer. In any case, when the thermometric determination gives a higher value than the resistance measurement, the former is to be taken. In testing railway motors a rise of 75° C. is allowed after one hour's continuous run at 500 volts, on a stand, with the motor covers removed. Higher temperatures than those specified are allowed in cases where the insulation is of a specially heat-resisting character. It is recommended that high dielectric strength should be specified in preference to high insulation, bearing in mind the fact that the latter can be largely increased by baking, to the detriment of the former. The conditions of testing for dielectric strength for machine insulation, including the testing voltages for the various values of the rated terminal voltages, are very fully specified. The lowest tested voltage is 1,000 volts, for rated terminal voltages not exceeding 400 volts. From 2,500 voltage to 10,000 rated voltage the testing voltage is double. From this to 20,000 volts rated, an access of 10,000 volts is to be employed; and after 20,000 the testing voltage is to be 50 per cent. in excess of the normal. Regulation and its determination, and methods of rating receive detailed consideration. The standard voltages recommended are: For direct-current low-pressure generators, 125, 250, and 550 to 600 volts; for low-pressure circuits, direct or alternating, 110 and 220 volts; for alternating-current primary distributing circuits, an average electromotive force of 2,200 volts; for high-pressure circuits, 6,000, 10,000, 15,000, 20,000, 30,000 and 60,000 volts. The standard frequencies suggested are 25, 60 and 120 to 140. The overload capacities recommended are: for generators, 25 per cent. for 2 hours; for motors, other than railway motors, and motors for intermittent service, 25 per cent. for 2 hours, and 50 per cent. for 1 minute; for synchronous converters, 50 per cent. for ½ hour; for transformers, 25 per cent. for 2 hours. Recommendations are also made with regard to photometric measurements.

G. W. DE T.

Electrically Operated Plant on the North Sea Canal.

(Engineering, vol. lxxiii. pp. 33–35, January 10; 105–107, January 24; 170–172, February 7; 243–245, February 21; and pp. 271–274, February 28, 1902.)

A full description of the North Sea Canal, the Ymuiden Locks, and the Port of Amsterdam is given, including a detailed and illustrated account of the electrically driven machinery employed for working the gates and sluices of the locks. The installation, which was the first of its kind, was carried out by the Haarlem

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Engine Works. The locks are provided with twelve gate-leaves, the largest of which weigh 140 tons each, and are 49·2 feet high by 77·5 feet wide; there are twelve chambers within the lock walls, each containing the machinery for operating one gate-leaf and one sluice, and two chambers, each containing the machinery for one capstan.

To open a gate within 80 seconds against a water-head of 4 inches requires 45 HP. Each gate-leaf is operated by one series-wound motor, running at 360 revolutions per minute, in a water-tight compartment. The motor drives chain-sheaves through worm-gear and double-helical gear-wheels, with a safety friction device; the chains are endless, and pull to and fro a four-wheeled carriage, which operates the gate-leaf through an iron boom. The sluices are operated through similar gear by motors, each of 17 HP., running at 270 revolutions per minute. Safety devices to prevent damage to the motors in the event of the gates or sluices jamming, or by over-winding, are provided. The capstans are driven by motors, each of 21 HP., at 270 revolutions per minute through toothed and bevel gearing. In case of emergency all the apparatus can be worked by hand; the gates and sluices can also be operated by means of the capstans.

A full description of the complicated switch-gear is given. All the operations are controlled from six switch pillars on the pier-heads, the reversing switches, which are fixed in the chambers with the machinery, being operated through pilot motors. The apparatus in each switch pillar consists of two simple throw-over switches, with a "current interrupter" in the base of the pillar. The power and lighting plant consists of two 75-kilowatt generating sets, and two engines driving smaller dynamos, together with a storage battery; light is supplied on the three-wire, and power on the two-wire system, at 350 volts. There are twelve 10-ampere arc-lamps, and 500 glow-lamps. The cables are all underground or under water; the former are lead-sheathed, the latter lead-sheathed and heavily armoured. At the Port of Amsterdam there are seven electric cranes, and a number of hydraulic cranes, driven by electric pumps, with a power-station containing two 75-kilowatt sets for power-supply, and two 30-kilowatt lighting sets.

A. H. A.

The Fayet-Chamonix Electric Railway.

(Engineering, vol. lxxiii. p. 573, May 2, 1902.)

This is a 3-foot $3\frac{3}{8}$-inch gauge line, 10·8 miles long. The sharpest curves are 490 feet in radius; and of the two steepest gradients, one is 1 in 11 over 1·35 mile, and the other is 1 in $12\frac{1}{2}$ over 0·85 mile. A third rail is employed for supplying current. At the gradients, a central rail is fixed between the track rails, on which a special shoe-brake acts, limiting the speed

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of descent to 6·25 miles an hour. The rails weigh 69 lbs. per yard, and the track rails are in 39-foot lengths, held on 15 sleepers by means of sole-plates and ordinary wood screws. Angle fish-plates are used for joining the lengths of both track and brake-rails. The contact rails rest on creosoted wood blocks. To prevent sliding action of the track down the gradients, a layer of concrete has been placed at intervals of 320 feet, in which old rails have been embedded; these act as abutments to the sleepers. There are two generating stations, one near Selvos and the other near Chavants, both being turbine-driven from affluents of the River Arve. The former contains four 325 HP. central discharge turbines, revolving on horizontal shafts. The first 140 feet of the fall are utilized for the head of water. Four 200-kilowatt, six-pole, continuous-current dynamos are connected to the turbines by elastic insulated couplings. The turbines are placed above the tail-race, have suction pipes, work under a head of 124 feet, and develop 320 HP. at 470 revolutions per minute. A 60-HP. out-flow turbine, running at 520 revolutions per minute, drives two 40-kilowatt exciters, which are also used to light the station. The second station contains two similar turbine-driven dynamos and exciter, but the head of water is here 308 feet. Each train consists of four or five cars with a luggage-van, and represents a dead load of 120 tons, for about 170 passengers. The heavy gradients made it necessary that each car should be provided with motors, and that they should be controlled by one driver only, from the head of the train. The controller is worked by compressed air, and operates the electric controllers on each car. A train of five cars, at a speed of 7·45 miles an hour, absorbs on the up-gradient of 1 in 11, 800 amperes at 550 volts. Starting on the same gradient absorbs about 11,000 amperes.

G. W. DE T.

Train-Resistance. W. J. DAVIS, Jr.

(Street Railway Journal, vol. xix. pp. 360–362; Discussion, pp. 362–367, May, and pp. 460–461, June, 1902.)

The Author, in view of the present tendency towards high speed, calls attention to the importance of obtaining a rational formula for train-resistance in place of the empirical ones now in use. The items to be considered are, according to him: (1) journal friction, taken as independent of speed; (2) rail-friction, assumed to vary as the speed; (3) wind-resistance, varying as the square of the speed, with the cross-section and end shape of the car, and with the number of cars forming a train. He writes down such a formula in the most general form, and determines the constants from tests made by him on a train composed of a locomotive, baggage-car, and three standard passenger coaches of the Erie

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Railroad, weighing on an average 26 tons each without load. The train was quickly brought up to maximum speed, when the power was thrown off and the train allowed to coast. Curves were obtained showing the variation of speed with time and with distance, with the locomotive alone, and with it and one, two, three, and four cars respectively. Examples of these curves are given. The formula so obtained is—

$$f = \frac{4 + 0{\cdot}13\,V + 0{\cdot}004\,A\,V^2\{1 + 0{\cdot}1\,(n-1)\}}{T_1},$$

in which f=friction in lbs. per ton; V=velocity in miles per hour; T=weight of train in tons; A=cross-section of car in square feet, including trucks, motors, etc.; n=number of cars, including locomotive. The cross-section A comprises the section of the car-body proper plus the section bounded by the car-wheels, the underside of the car-body, and a horizontal line, tangent to the head of the rails, and normal thereto. *Discussion.*—J. Lundie criticises the method employed in obtaining the formula. He considers that important items are omitted by the Author, *e.g.*, the lack of perfect resilience in the parts, both of the track and rolling stock, which are under strain. He proposes a formula, which, in addition to minor modifications, substitutes the first power of the speed for the square. S. T. Dodd insists on the importance of obtaining more extended data, and points out discrepancies in the results given by the Author's formula with those obtained in the Berlin-Zossen trials. L. Bell also comments on these discrepancies and distrusts the coasting method employed in the tests. H. V. Wille compares the Author's formula with that employed at the Baldwin Locomotive Works, and finds a fairly close agreement. The Author, in replying to the various criticisms, maintains his conclusions, and quotes a number of experimental results tending to support them. He admits, however, the great importance of further and exhaustive tests, especially on high street cars vestibuled at the end. He states that the General Electric Company of America is now making arrangements to conduct a series of such tests up to the highest speeds within the capacity of the track and equipment available for the purpose.

G. W. DE T.

Electro-Pneumatic Railway System. B. J. ARNOLD.

(Amer. Inst. Elect. Engin., Trans., vol. xix. pp. 659–662, May, 1902.)

This Paper gives a preliminary account of a system of electric traction, upon the designing of which he has been engaged for a considerable time, and which is to be tried on a 60-mile length of railway, of which 20 miles are now nearly completed. The system

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consists essentially in the use of a single-phase (or polyphase, if desired) alternate-current motor in which both the rotor and the stator, or portion which usually remains fixed, are made capable of rotation, and each is connected with an air-compressing engine and storage reservoir. This motor is designed for the average power required, and runs continuously at constant speed and constant load, and, therefore, at maximum efficiency. When the car is at rest, the stator runs at what is known as synchronous speed, which depends only on the rate of alternation of the current, and compresses air into the storage reservoir. To start the car, the air-compressor connected with the rotor is throttled, diminishing the speed of the stator. This causes the rotor to turn in the opposite direction, since the mutual action of the stator and rotor keeps the relative speed constantly at the speed of synchronism. By increasing the throttling, the speed of the rotor will be increased until it attains the speed of synchronism, when the stator will be at rest. If a still higher speed is desired, the stator is turned in the same direction as the rotor, by admitting air from the storage reservoir to the engine in connection with the former. If a higher starting effort is required than the motor can exert, then the rotor is turned by the admission of air to the engine in connection with it. This arrangement enables a car to ascend an incline at any desired speed up to the maximum, and with the motor working at its highest efficiency and imparting its full power to the car. In descending, the motor may, as desired, either utilize the full power derived from the line, or may be used to compress air with the stored energy of the train, thereby acting as a brake. In case of the supply of current being cut off for any reason, the car can be run for a considerable distance by means of the store of compressed air, and the Author points out that this feature will enable a car to work on a high-pressure trolley wire over private right-of-way, and allow the trolley-wire to be dispensed with, if necessary, when this ceases, so that a car can pass through a town on any line of rails, whether electrically equipped or not, until it reaches the outskirts when it can be again connected to the trolley-wire. This feature will also be of value in switching-work, for each car, being independent, can leave the main-line track, and operate over switches or sidings, without complicating the yards with additional overhead or third-rail conductors, thus necessitating trolley-line conductors over the main-line track only. If a single-phase motor is used, only one overhead or third-rail conductor is required, and only one of the track rails need be used for the return, so that the other one may be left free for an automatic signal system if desired. The current can be taken into the car at any pressure up to the limit of the insulation (15,000 volts is to be used on the line now in course of construction), and led to the motor through a static transformer to effect its reduction to any desired value. The power-station will always work at practically constant load, which will greatly reduce the requisite size of the plant and conductors. All the controlling operations are mechanical, no alteration being made in

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the electrical circuits, and all the operations being effected by means of the controlling lever of the motor-man, as in the systems now in use.

G. W. DE T.

Relative Cost of Steam and Electric Railway Operation.

B. J. ARNOLD.

(Amer. Inst. Elect. Engin., Trans., vol. xix. pp. 623–657, May, 1902.)

The Author was commissioned, in August, 1901, by the New York Central Railroad Company, to study the conditions governing the operation of its trains between Mott Haven Junction and Grand Central Station, and to report upon the feasibility of operating them electrically. This division consists of 5·3 miles of quadruple track, of which 2 miles are underground, and it was the annoyance caused to passengers, due to the use of steam locomotives in the tunnel, which led the company to examine into the advisability of adopting electric power. A most elaborate series of investigations was carried out by means of a dynamometer test-car inserted between the locomotives and trains run on each section of the road under ordinary service conditions, and from the results of these, and a very complete analysis of the traffic conditions, it was found that the electrical energy required to haul a ton 1 mile over the division under the existing conditions would average 63 watt-hours. No less than twelve alternative systems of electric-power distribution were then examined in detail. Some of the least costly of these had to be rejected, owing to their requiring the location of power-stations in positions where their erection would probably have been prohibited by the City authorities. The system ultimately recommended was one with a combined alternate- and continuous-current power-station near one end of the division, with a sub-station near the other end, with batteries in both stations. The alternate current was to be transmitted at a voltage of 11,000, and the continuous current at a voltage of 600. With this system it was found that, on the assumption that the electric locomotives would be operated by the same number of men at the same wages as those required for the steam locomotives, the total costs per locomotive-mile came out at 24·18 cents for steam and 23·63 cents for electricity. With regard to these figures, the Author of the Paper observes that they could be made more favourable to electricity were an optimistic view of many of its advantages taken, and that it was probable that in practice the gain would actually be greater. He preferred, however, to maintain a conservative view throughout the investigation, but considered it safe to conclude that the saving in working expenses by the electric system would be sufficient to offset the increased fixed charges due to the

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additional investment made necessary by its adoption. The constituents of the total cost were made up as follows:—

	Steam.	Electricity.
	Cents.	Cents.
Operating expenses per locomotive mile, exclusive of fixed charges, but including water, labour, cost of cleaning and repairing tunnel, and all other expenses of locomotive operation.	23·05	15·80
Fixed charges per locomotive mile, assuming that it now requires forty locomotives to perform the present service, and that thirty-three electric locomotives could perform the same service	1·13	7·83
Total	24·18	23·63

If the multiple-unit system were adopted, as it would be if the electrification were extended over the rest of the line, or if the forward guard or brakeman were allowed to take the place of the second man while passing through the tunnel and yards, where two motor-men in charge of each locomotive were considered advisable, a saving in wages would be added to the foregoing.

G. W. DE T.

Determination of Grades and Alignment.

(Railroad Gazette, vol. xxxiv. pp. 323–324, May 2, 1902. Extract from the report of the Committee on Roadways of the American Railway Engineering and Maintenance of Way Association.)

In considering the question of grade with reference to economy, it is not always the grade which limits the weight or length of a train, as the limiting grade is a virtual grade which may be different from the actual one, due to a difference in velocity at the top and bottom. When the surplus energy stored in a train is drawn upon to allow of less tractive effort than would be necessary if uniform speed were maintained, we have a momentum grade. The practical problem for the engineer is to determine either (*a*) how far a steep actual grade can be continued, and yet allow a required virtual grade to be maintained; or, where an actual grade is under consideration, to determine (*b*) what the virtual grade will be under prescribed conditions of operating; and also to find (*c*) the speed which it is possible to acquire at the foot of a momentum grade. The points are dealt with at length in the report, and an interesting series of diagrams accompanies the text.

C. E. A.

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Torsional Stress in the Connection between the Ship's Engines and the Propeller. H. Frahm.

(Phys. Zeitschr. 3pp. 481–488, July 15, 1902. Paper read before the 73rd Naturforscherversammlung at Hamburg.)

The experiments described were carried out on vessels constructed by Messrs. Blohm and Voss. In large steamships the distance from the engines to the propeller is so considerable that the connecting pieces cannot be regarded as rigid, but must be looked upon as more or less elastic springs kept in torsion by the turning movement communicated to the propeller by the engines. If the engines revolved uniformly, the torsion in the connection would be constant, but variation in the speed of the ordinary engine causes variation in the torsion and in the speed of the connecting pieces and propeller. Two very thin pieces of zinc leaf, coated with a prepared conducting oxide, are fastened round the connecting piece as far as possible apart; against each of those presses a platinum point; when an elastic current flows (but not unless) the points record a mark on the prepared surface. The position of the points is marked exactly when the connector is free from torsion. After the engines have run steadily for a time the platinum points are caused by a suitable arrangement to move forward parallel to the axis of the connector, the current being allowed to pass, so that marks are recorded on the prepared surface. On the interruption of the current the record ceases. Since both marks are made in the same time, the velocity curves can be got by placing the zinc leaves in different positions on the connector. The displacement of a point on the connector can be got similarly by placing the zinc leaves close together so that when the connector is free from torsion the marks are exactly above each other; from this the torsional stress can be calculated; also from the curve so drawn the mean turning moment transmitted to the propeller can be easily calculated, and the b.h.p. found; the modulus of elasticity was found by separate experiment on specimen connectors. The results show the connector vibrates much more than would be expected from the variations in the speed of the engines, the stress during a revolution sometimes rising to three times the mean value and going back through zero to the same amount in the opposite direction; hence a probable cause of fracture of propeller shafts.

W. S.

Tests of Steam-Pipe Coverings. G. H. Barrus.

(Amer. Soc. Mech. Engin., Trans., 23. No. 952, pp. 791–837; Discussion, pp. 837–845. 1902.

This is an extended Paper on a subject already treated shortly by the same Author. It contains illustrations of the apparatus employed, diagrams and tables of the results. In his conclusions

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the Author points out the fact that the most efficient covering was the one most closely resembling hair felt in its texture. In air-cell coverings those are most efficient in which the corrugations forming the air-cells extend circumferentially round the pipe, as compared with cells extending lengthwise. As regards the relative efficiencies of high- and low-pressure coverings, the high-pressure coverings give the best results, even with low-pressure steam; and although they are 70 per cent. dearer in first cost, they are cheaper when tested over a period. The average cost of the high-pressure coverings at the end of five years' service with 80 lbs. steam pressure (taken on the basis of cost given in Table 8 accompanying the paper) is $14,693, whilst the low-pressure coverings in same time cost $18,525. The relative efficiencies are expressed in cost of coal required to supply the heat lost by radiation. In the discussion W. Kent stated that the cost of allowing pipes to go uncovered with steam of 80 lbs. pressure was, according to the Author's results, $1·27 per square foot of pipe per annum, and with steam of 150 lbs., $1·61, and that these latter figures would be reduced to 30 cents by using the worst of the coverings tested, and to 22 cents by the best.

F. J. R.

Liquid-Fuel Combustion. C. E. Lucke.

(Amer. Soc. Mech. Engin., Trans. 23. No. 936, pp. 483–508; Discussion, pp. 508–510, 1902.)

The Author recounts a long series of experiments with variously arranged burners for liquid fuel, in which he aimed at producing combustion in a closed chamber so that heated gases might be delivered with regularity to a hot-air engine. The general tendency of his results was to direct him away from special vaporisers and towards automatic regulation, with vaporization taking place in the fire-box in presence of air, the simplest arrangements being the best. He finally evolved an apparatus feeding oil or gas and air simultaneously in explosive proportions into a mass of broken rock, which became intensely hot underneath the surface and throughout the mass. Excess of oil or of gas could be burned on the surface without interfering with the "explosive combustion" taking place in the mass. There are many diagrams of experiments in the Paper, and photographs of the completed apparatus at the end.

F. J. R.

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Insulated Lines in India. K. A. Scott-Moncrieff.

(Inst. Elect. Engin., Journ. 31, pp. 371–379; Discussion, pp. 379–387, 1902.)

The insulation of bare wires on insulators varies owing to the humidity of the air, the effect of which is increased by spider's webs. Vulcanized indiarubber as an insulator did not prove a success in Calcutta at 1,300 volts. In consideration of the heavy rainfall, difficulty would be met in draining; a culvert system, in which the cables, insulated with vulcanized bitumen, are laid upon wooden bridges in a cast-iron trough, was tried. The drawback of iron troughing is that a fault rapidly becomes a real short circuit, so much so that in some cases several feet of cable have disappeared through this cause. Faults also develop at the bridge-pieces. In every case where faults developed it was at a bridge-piece which came at the junction of two troughs and where there was a subsidence of the ground. The Author thinks that the bitumen cracks at a weak point instead of bending gradually. The only other source of trouble has been where the bitumen was poured into the troughs when boiling. The surface rapidly cooled and prevented the steam escaping, thereby making a spongy casting.

For house circuits.—Owing to the humidity of the air, surface leakage on switches, cut-out and other fittings is much increased. Some damage results from surface leakage destroying the metal parts of switches by electrolysis. Insufficient insulation of switch-handles, even if ebonite, on a main switch on a 230-volt alternating circuit has given some trouble. The wiring in the mils around Calcutta was largely carried out with conductors insulated with a little pure rubber, protected by cotton. Even with such low-class work little or no trouble has occurred. The failure of wires covered with good rubber is due to exposure to damp and heat, and no ventilation. The wires are shut up in a casing, and the whole becomes wet and rots. No insulation will stand under these circumstances. Interior conduits made of 1-inch compo-pipe has stood well for the last six years. Large pipes should be used, so that the insulation may be ventilated.

M. O'G.

Soulanges Canal Electric Plant.

(Canad. Elect. News, 12, pp. 93–97, June, 1902.)

Owing to the fact of a good water power being available on the canal it was decided to install an electric plant for the operation of the locks, sluices, and bridges, and to light the canal throughout its entire length. On account of the length of the canal the

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alternating current three-phase system was adopted. There are two wheel pits, in each of which are installed two pairs of Victor turbines on one horizontal shaft, operating under a 20-foot head at 225 revolutions per minute, and discharging into the Grease River, which acts as a tail-race. Each set of wheels is furnished with a Geisler governor. To each water-wheel unit is coupled a three-phase revolving field, 60-cycle generator of 264 kilowatts capacity at 2,400 volts, furnished by the Canadian General Electric Company, each being set on concrete foundation capped by heavy dressed stone. Two four-pole exciters are furnished, each of 17 kilowatts capacity at 125 volts, being sufficient to excite the fields of both generators. These are driven by belts from the main water-wheel shafts. Crossing the canal at intervals are five electrically operated bridges. The motors and controlling apparatus are contained in a cabin at the side of each bridge. The motors are of 2-HP. capacity, operating at 220 volts, and are geared to the mechanism for turning the bridge. Between the electrical mechanism and the bridge gearing a flexible friction is interposed, which is operated by a lever, and acts either as a clutch or a brake as occasion requires. The bridges each weigh upwards of 100 tons, and the mechanism is designed to open or close them within ten minutes. Power is conveyed to the bridge by means of submarine cables from transformers placed on one of the line poles adjacent to the bridge. The lock gates and sluice valves are operated by the Canadian General Electric Company's three-phase 220-volt constant-speed induction motors in the following manner: The lock gate motors are of 3-HP. capacity, and are connected to the pinion which operates the rack by a pair of gears. At one point, however, is interposed a friction device which is so arranged that by operating a lever two friction-pulleys can be brought into contact, thus applying the power to move the gate, and by reversing this lever a powerful brake is applied, which is used to arrest the motion of the gate, and thus prevent it striking with more than necessary force the mitre sill when closing or the recess when opening. The motor can be reversed in a few seconds in case of emergency. The electrical apparatus installed along the canal is very effectively protected against lightning, lightning arresters of the Canadian General Electric Company's short-gap tyre being installed at each lock and at every point where cables pass under the canal for lighting, power, or telephone services. The operation of the sluices, locks, and bridges by electricity has been found to result in a saving of labour equal to 50 per cent., there now being required for the operation of the locks only two men instead of four as previously.

G. W. DE T.

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Water-power in Ireland. W. Tatlow.

(Inst. Elect. Engin. Journ., 31, pp. 1146–1157; Discussion, pp. 1157–1169, June, 1902.)

The author examines in great detail the various water-powers available in Ireland. In 1839 water-power to the extent of 2,147 h.p. was in use in the island—the amount is probably not greatly exceeded to-day. About 800 h.p. is in use for electric supply. Much of the power is available only in small amounts, and the author proposes "collecting" as distinguished from "distributing" systems to pick up the power from many such stations and employ it in a single factory or electrochemical works. To reduce the amount of skilled labour required, he proposes to use induction generators at the smaller power-houses. Tables are given showing the catchment areas of the principal rivers, as well as the levels and areas of the lakes, and the importance of these for regulating and storing the water pointed out. The author urges the importance of the collection of systematic data as to rainfall and river levels at different times of year, and suggests that the Government might instruct the Constabulary to take observations. In the Discussion, W. F. Barrett (chairman), suggested that considerable power might be available in Dublin from the water-supply. M. Harriss dwelt upon the great importance of obtaining permission to use bare overhead conductors for electrical transmission. J. Perry discussed the possibilities of electrical accumulators for compensating irregularities in water-supply, and estimated the cost of maintenance and interest on the battery at present as £10 per h.p. per annum working a ten-hours' day. W. Tatlow, in reply, pointed out that the length of pipe-line for the Dublin water-supply was so great that the head would be practically all taken up in friction unless the diameter were excessive. He also pointed out the importance of pumping water into high reservoirs as a means of storing power as proposed for Arthur's Seat in Edinburgh, and as actually practised in Zürich, where a reservoir at 475 ft. head stored 5,000 h.p.-hours, and at Geneva where 4,000 h.p.-hours were stored with a head of 390 ft. A. E. L.

The Edison Company's Station, Boston. I. E. Moultrop and R. E. Curtis.

(Amer. Soc. Mech. Engin., Trans. 23, No. 942, pp. 569–590; Discussion, pp. 590–593, 1902. Paper read at the Boston meeting, May, 1902.)

The authors here deal with general considerations in connection with the design. The main points insisted upon were the necessity of having the switchboards in a central position, and the importance of arranging the station in such a way that no conceivable accident could necessitate the entire suspension of operations even for a moment. The switchboards

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are arranged in two halves, on balconies facing each other, the whole being separated from the rest of the station by substantial brick walls, terminating several feet above the roof. The switch-board rooms are on two floors, and will be extended upwards; the floors are of slate on steel framework. The machines are connected to motor-worked switches, carrying upwards to 7,000 amperes, mounted on cast-iron posts, one series of posts being for positive and one for negative switches. The motors are mounted on the tops of the posts, and the switches are controlled by selector switches on the operating table. The steam pipes were originally arranged on the ring system, with a plentiful supply of valves, but this arrangement has been abandoned, and each engine is now connected to certain boilers, and can, if needed, be also connected to those in the immediate neighbourhood. Diagrammatic plans of the steam piping are given. The distributing pipes are now 12 in. in diameter, and are limited to 50 ft. in length, being anchored near the middle of each length. Sliding bearings are preferred to roller bearings, as eliminating vibration. Neither copper pipes nor screwed flanges are used; the steel flanges are welded on. Joints are tongued and grooved, and made up with thin corrugated copper gaskets. All valves controlling branches from the boilers have auxiliary valve stems, which are taken through brick walls to points where they can be safely worked under any conditions. The condensers are at some distance from the engines; the main portion of the exhaust pipe is made of riveted steel plates, and is 50 in. in diameter, all seams being caulked inside and outside, and all joints butted with outside straps. The construction and details are fully described. Superheating is used, and its application will be extended. The amount of superheat at present varies with the position of the engine, from 100° F. at the throttle valve downwards. A notable economy of coal is considered to result from superheating, and figures are given showing results obtained. The coal-handling plant consists essentially of a steel pocket, running the full length of the wharf, with storage space in the rear; three unloading towers traversing the top of the steel pocket; bunkers in the boiler-house, supported by the roof trusses; and an elevated cable railway, travelling over all the above, with self-dumping cars of two 1/2 tons capacity. Some of the larger exhaust valves are being worked by motors, which are controlled from distant points, and it is regarded as certain that all valves of more than 24 in. diameter will soon be so worked.

W. H. S.

Concord N.H. Water-power Plant.

(Electrical World and Engineer, 40, pp. 45–47, July 12, 1902.)

This plant was installed in 1892 in a water-power station situated at Sewalls' Falls on the Merrimac River about 4 miles from the town of Concord. Across the river a dam about 500 ft.

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long was built, enabling a fall of 16 ft. of the entire flow of the river to be used for generating power. At this station in the year above mentioned three-phase generating plant was installed, the minimum capacity of the station during the dry season being rated at 2,500 h.p. It was found necessary to employ an auxiliary steam plant to take the load during the early portion of the winter when the anchor ice became troublesome; but the period of such use is only of short duration. In 1901 the water-wheels and generators were replaced by plant of larger capacity. The new water-wheels comprise five pairs of horizontal turbines, each pair being 36 in. in diameter and rated at 300 h.p. when operating at 140 r.p.m., under a head of 15 ft. of water. The three-phase generators, which are belt-driven, are of the revolving magnet type, with a capacity of 200 kw. at 2,600 volts, and supply current at 60 cycles, the combined capacity of the generators being thus 1,000 kw. These generators supply the current for incandescent lighting and power to the village of West Concord, which is situated 2 miles from the generating station, and also to a substation at the business centre of the town of Concord about 4½ miles away. The transmission is by means of overhead wires, partly at 2,500 volts, and partly at 10,000 volts, the voltage in the latter case being raised by transformers at the generating station. The energy transmitted at 10,000 volts is partly supplied to the shops of the Boston and Maine Railway which are distant 5½ miles from the power station. At these shops two transformers of 200 kw. capacity each change the energy from three-phase 10,000 volts to two phase at 440 volts. The local city circuits are supplied directly at 2,500 volts, but owing to the increasing losses in the distributing mains, the load is being gradually changed over to 10,000-volt transmission circuits. The transmission wires cross the Merrimac River by a span 700 ft. long. For the commercial local service in Concord, the 2,500-volt circuits extend generally over the city, and in the business centre, a closed loop of about 1 mile in length is run, to avoid the frequent use of small transformers. This loop is composed of three primary and three secondary wires between which transformers are connected, three p.d. between the secondaries being 110 volts. From the secondary loop, service wires are carried directly into the premises of consumers. The arc lighting of the city is supplied at 2,500 volts from separate circuits which do not pass through the substation. The current is generated by two direct-current arc dynamos having a capacity of seventy-five 1,200-c.p. lamps, and driven by one of the old three-phase generators which is now used as a motor of 150 h.p. The auxiliary steam plant is installed at the substation, and consists of a Babcock-Wilcox boiler, rated at 600 h.p., supplying a 500-h.p. compound engine which is belted to a 450-kw., three-phase, 60-cycle, 2,500-generator. Tables are given showing the capacities of the various transformers, motors, and meters in use.

J. G.

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Brakes for Tramcars. C. J. SPENCER.

(Tramway Railway World, 12, pp. 87–88, July 5, 1902. Paper read before the Association of Municipal Tramway Managers, July, 1902.)

Results of some brake tests made on a single track 52-passenger car at Bradford. The tests made were on a level track with a wet rail, and the car, which was equipped with hand, electric and slipper brakes, was drawn by two ordinary cars through a dynamometer drawbar. A second dynamometer was connected to the pull-rod of the slipper brake, from which the downward thrust of the wooden slipper block against the rail was calculated. With the hand-brake alone a maximum retarding effort of 2,050 lbs. was reached, before the wheels skidded. On locking the wheel, causing skidding, the figure fell to 1,600 lbs. With the slipper brake alone the maximum retarding effort was 950 lbs., the corresponding pressure on the rails being 4,300 lbs. With the hand-brake in addition the combined retarding effort was 2,450 lbs., showing an advantage of 400 lbs. over the hand-brake alone. This is under the worst conditions (for the slipper), viz., a wet rail. A greasy rail cannot exist on steep gradients where the slipper is in constant use. Two charts based on the tests are given.

F. B.

Tests of Steam Turbine at Hartford, Conn. W. L. ROBB.

(Elect. World and Engineer, 40, pp. 360–361, Sept. 6, 1902.)

The turbo-generator installed at Hartford is rated at a capacity of about 2,000 kw. The steam used for the turbine tests was superheated about 33° F. The load during the months of January, February, and May varied from 364 kilowatts in May to over 2,000 kilowatts in February. The steam pressure was kept at about 150 lbs., barometer 30 inches; vacuum at turbines from 26·9 inches to 57·4 inches; coal consumption per electric-HP. hour from 1·28 lbs. to 2·49 lbs., or per kilowatt-hour from 1·70 lbs. to 3·32 lbs. The steam consumption per electric-HP. hour was from 14·43 lbs. to 25·10 lbs., or per kilowatt-hour from 19·10 lbs. to 33·47 lbs.

L. G.

The Garbage Furnaces of Trenton.

(Engineering News, 48, pp. 197–200, September 11, 1902.)

This is a reproduction in print of the report made by R. Herring, of New York, to the Committee "appointed to investigate the working of the city crematory, against which numerous complaints

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have been made." It is said to be the first complete engineering investigation of the operation of an American garbage furnace which has been published, and is expected to mark an era of improvement in garbage disposal there. The causes of complaint are ranged under the following heads which are treated separately: (1) Collection of garbage and odours arising from it when delivered at the works. (2) Odours from the ashes after their removal from the furnace, when retaining some incompletely burned material. (3) Dust of completely burned garbage escaping from the stack and depositing in the neighbourhood. (4) Unburned or still burning particles escaping from the stack and depositing in the neighbourhood, with the possibility of causing fires. (5) Odours due to the unburnt gases escaping from the stack. The destructor plant reported upon consists of two furnaces of the Davis type connected by separate flues to a brick chimney of 5 feet square internal section, about 120 feet high from the base, and 100 feet above the entrance of the flues. Each furnace consists of a drying chamber at the back, 8 feet square and 8½ feet high to the crown, and a combustion chamber at the front, 4 feet long, 6 feet wide, and 4 feet high, on the same level as the drying chamber, both having horizontal grate bars about 4 feet long and 4 inches wide, with ½ inch openings for the fire grate and ¼ inch wide for the drying grate. The main flue is about 3 feet wide by 3½ feet high, and there is a secondary flue 4½ feet long, 5½ feet wide, and 3 feet high, containing some short grates on which coal is kept burning for the purpose of destroying odours passing from the furnaces. The refuse is similar to that of other towns (see Table).

——	London.	Berlin.	New York.	Boston.	Trenton.
Authority	Codrington	Bohm and Grohn	Craven	O'Shea	Committee.
Kitchen garbage, animal, and vegetable matter .	77	82	64	84	84
Paper	23	11	28	16	12
Rags, clothing, carpets, &c.		3			3
Boxes, barrels, and other rubbish		4	8		1

American experience of destructors is considerably behind that of countries in Europe; the American furnace has larger grate area and horizontal instead of sloping bars. Irregular burning is caused by the dumping of damp refuse on such grates; and the rate of combustion and of travel of the waste gases is, especially at Trenton, much too high. The amount of garbage burned in each English cell depends on its composition and moisture, but with proper drying it is usual to burn 5 to 7 tons per day per cell of 25 square feet grate area; and the quantity of unburnt coal mixed with the ashes in the collected refuse furnishes all the combustible required to ensure thorough burning. In Trenton the quantity burned per day is almost 14 tons, and to aid combustion about 120 lbs. of

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additional coal per ton of refuse are used. In consequence of the confined area of flues and of badly designed dampers, the velocity of the currents of waste gases is too great. With proper grate area for the burning of 30 tons per day the volume of air required for the combustion would be about 150 cubic feet per second, which would demand a sectional area of at least 100 square feet in the flues, or more than four times the existing area. The writer recommends the erection of new furnaces of the English pattern, and drying chambers, with sloping floors to aid in drawing off moisture from the refuse, and also in moving charges into the furnace; a better arrangement of dampers to control the draught towards the chimney at different periods of the work; more flue area and the interposition of a dust-settling chamber between the furnace and the chimney. The furnaces should be worked with forced combustion, and all the unburned coal collected with the refuse should be left in it, in order to save the additional coal at present used. The gases should leave the furnace at a point above the hottest fire, and should be utilised to heat the walls of the drying chamber, and assist in preparing the garbage for burning. There are also several minor recommendations which deal with the transit and stowage of the refuse.

F. J. R.

Gola's Lightning-Arresters.

(Elektrotechn. Zeitschr. 23, pp. 455–457, May 22, 1902. From a Paper read by G. Gola before the Associazione Elettrotecnica Italiana in Milan.)

The principle of Gola's arrester is to so arrange a magnetic field as to prevent a discharge passing through the arrester along the line, and direct it into the path it should take to earth, across a spark-gap. The arrester consists of two semi-ellipsoidal shells of iron, fastened together by bolts, with a ring of zinc interposed. Covering the upper half is another iron shell separated from it by an air-space, but in metallic contact through bolts. This covering shell and the lower shell form the pole-pieces of an electromagnet, so that there is a magnetic field in the air-space between the covering shell and the upper shell, and in the zinc ring between the upper and lower shells. Opposite the two ends of the major axis of the ellipsoid are two carbon poles, fixed in independent insulators and connected to earth. Between these and the ellipsoid is the spark-gap. The outside conductor is attached to the upper shell and its covering shell, and connection is made from inside of the zinc ring by a terminal passing through the lower shell and insulated from it. From this the current goes through the electromagnet and to the apparatus to be protected. The magnetic field across the zinc ring makes the passage of a lightning discharge through it very difficult, and, further, the magnetic field between the upper shell and its covering directs the discharge to the ends of the major axis

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of the ellipsoid, and forces it to take the path through the spark-gaps instead of through the zinc ring. This action enables the spark-gaps to be made twice as long as in other arresters, and does away with the necessity of any mechanical arc-rupturing device. The arresters have been tried on a line supplying power in the Apuanian Alps, in a situation peculiarly susceptible to discharges. From October, 1900, to May, 1901, the line which was protected by horn arresters was struck four times, and the machines damaged. Since that date when two Gola arresters were installed, no lightning discharge has reached the station.

G. H. B.

Electricity in Iron- and steelworks. F. KYLBERG.

(Iron and Steel Ins., Journ. pp. 2–16, Sept., 1902.)

The author first refers to the successful use at the Differdingen Ironworks and at the Düdelingen Eisenhütten-Aktienverein in Luxemburg of waste blast-furnace gases for driving gas-engines for generating electric power. He then describes with drawings a number of different kinds of electrical appliances employed at different steel works. An interesting procedure is that described by the author as used in American steel works for saving time and labour in casting the steel "blooms." An electric crane lifts the casting ladle over a train of small cars containing the ingot moulds, and, as each mould is filled, an electric adjusting gear brings the next car with its mould under the crane, thus avoiding any moving of the crane with its enormous mass of molten metal. Great force is required in "stripping" or drawing the "blooms" out of the moulds, and formerly hydraulic power was invariably employed for the purpose, but in the Bethlehem Steel Works an electro motor-driven screw press is employed, which greatly accelerates the process, while at the same time effecting a considerable economy of power. The same crane then lowers the ingots into the "soaking pits," in which the outer portion of the ingots is kept hot until the inside portion has had time to solidify, when they are ready for the rolling mill. The introduction of electric driving for the rolling mill accessory apparatus not only effects a great economy in comparison to the hydraulic methods formerly employed, but has rendered possible the use of automatic means of maintaining the thickness constant. This is a matter of the greatest importance in the case of tyres and many other rolled products. With the hydraulic system, hand regulation, depending on the workman's sense of touch, had to be relied upon. The chief difficulty in maintaining the right pressure lies in the uneven temperature of the ingot, which tends to cause a greater reduction in the thickness of the hotter portions of the "bloom."

G. W. DE T.

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Electrical Power in the Iron and Steel Industries.

D. SELBY-BIGGE.

(Iron and Steel Inst., Journ. pp. 3–32, Sept., 1902.)

This Paper deals mainly with figures showing the economy effected by driving electrically the machinery employed in iron and steel works, and machines of a similar character elsewhere. Striking examples of this are given in the case of the quayside cranes at Hamburg, where the introduction of electric power in the place of steam reduced the cost per ton lifted from nearly 2¾*d.* to just under a penny. In a Northumberland colliery an electric plant costing £3,000 was used to replace steam for driving seven pumps, each delivering about 100 gallons a minute and was found to effect an annual saving of over £1,500. In the Ewald Colliery, in Germany, the replacement of horse haulage by electric reduced the cost by about one-half after allowing for interest and depreciation.

G. W. DE T.

Effect of Closed Slots in Stator Cores of Induction Motors.

W. MOLLIER.

(Elektrotechnische Zeitschrift, 23, pp. 670–673, July 31, 1902.)

The author gives an account of some experiments on the effect of converting the closed tunnels of a stator core into open ones—which is the general present-day practice. The effects produced by opening the slots may be briefly summarised as follows: The magnetising current is increased on account of the increase in the reluctance of the leakage paths; for any given load, the stator current is larger, the overload capacity greater, and the slip less, than in a stator with closed tunnels; the power-factor is at light loads less, but at heavy loads higher, than with closed tunnels. The author's experiments show that an extremely narrow air-gap—say 0·3 millimetre—cut through the bridge-pieces of the slots is sufficient to produce very marked effects.

A. H.

Protection of Electric Transmission Lines against Lightning.

DUSSAUGEY.

(Soc. Int. Élect., Bull., 2, pp. 633–658; Aug., Sept., and Oct., 1902.)

This Paper contains a discussion of the principles involved in the design and application of lightning arresters for the protection of electric transmission lines. The various arresters at present in

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use are dealt with, and attention is called to a new form of arrester, designed by the author, which has been in actual operation for some time with very satisfactory results on the transmission line between Voiron and Grenoble, France. The apparatus was designed to dispense with the costly reactances which are usually placed in series with the arrester-gap and earth. The author finds that sufficient reactance can be obtained by forming sharp angle bends in the line conductor round insulators on the lightning arrester supports. The arrester consists simply of a pair of curved horns attached to the line conductor. The earth connection is made with a vertical rod which is situated in the middle of the gap between the horns.

The author discusses fully the precautions to be taken in distributing arresters over a transmission system, and points out the necessity for periodical rigorous inspection of all the apparatus if reliability in operation is to be expected. He concludes the paper by suggesting that in view of the limited experience in the protection of long-distance transmission schemes, some concerted action on the part of European engineers in charge of such schemes should be taken with the object of obtaining accurate information from systematic series of extended observations of the atmospheric and other conditions affecting the operation of arresters. The paper is accompanied by diagrammatic illustrations of a number of different forms of arrester apparatus.

J. G.

Detroit, Ypsilanti, Ann Arbor and Jackson Railway.

F. E. MERRILL.

(Street Railway Review, 12, pp. 537–542, September, 1902.)

The system has grown up since 1897 and now comprises 60 miles of line. The track is laid with 75-lb. rails on 8-foot cedar sleepers laid 2 feet centre to centre. The rolling-stock consists of thirty-three standard closed cars and four open ones. A special roller-bearing trolley wheel is used and a travelling trolley base, running on angle irons the whole length of the car, so that it is always at the rear end whichever be the direction of motion. Spoked wheels, 36 inches diameter, weighing 575 lbs. each, are used on $5\frac{3}{8}$-inch steel axles. The treads are $2\frac{1}{4}$ inches broad, with $\frac{1}{16}$-inch flanges. The older parts of the line are supplied with power by a continuous-current station at Dearborn, while at Ypsilanti is an alternating-current station feeding six sub-stations. There are eight 225-HP. Babcock and Wilcox boilers, with Roney mechanical stokers. Five 250-kilowatt three-phase generators, and three 250-kilowatt double-current generators, all of Westinghouse make, are coupled to Westinghouse engines, 18 inches and 30 inches by 16 inches, running at 250 revolutions per minute. Three 500-kilowatt self-cooling, oil-

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insulated transformers are used to step up the voltage from 390 to 22,000. There are three circuits, one east to Wayne and Dearborn sub-stations, 20 miles, one west to Ann Arbor, Lima Center and Francisco, 30 miles, and one to Michigan, 41 miles.

A. E. L.

Detroit United Railway Power-Stations. T. FARMER.

(Street Railway Review, 12, pp. 518–525, September, 1902.)

The Author describes the six power-stations and three accumulator stations of the system, which are as follows:—*Station A.*—Near the business centre of the city. It contains twelve Babcock and Wilcox boilers 250 HP. each, with Murphy stokers and Hoppes' live steam purifiers. There is a Hunt conveyor for coal and ashes, and a steel smoke-stack 180 feet high and 11 feet 6 inches inside diameter. Four Reynolds-Corliss compound condensing tandem engines, 28 and 52 by 48 inches, are direct-connected to 1,000 kilowatts Siemens and Halske outside armature generators. *Station B.*—This is close to station A, and is controlled by the switchboard in the latter. It contains eight Sterling boilers of 300 HP. each, and 8 of 250 HP. each, with Murphy stokers, Green economisers, and a brick stack 185 feet high with 10 feet flue. There are two Reynolds-Corliss cross-compound condensing engines, 20 and 40 by 48 inches, direct connected to 400 kilowatts Walker generators, two similar engines, but 24 and 48 by 48 inches, connected to 800 kilowatts Walker generators, and one Filer and Stowell cross-compound condensing engine, 32 and 64 by 60 inches, connected to 1,500 kilowatts Westinghouse generator. *Station C.*—A battery station situated opposite to Station A. This contains a battery of 276 chloride cells, having each 67 plates $15\frac{5}{16}$ inches square. The discharge capacity is 2,500 amperes at 575 volts for one hour, 1,250 amperes for 3 hours, or 625 amperes for 8 hours. A 250-kilowatt booster is used for charge and discharge. *Station D.*—This is at Farmington Junction, 19 miles from the City Hall. It contains eight Aultman and Taylor boilers of 250 HP. each, with Murphy stokers, and three Reynolds-Corliss engines, 26 by 48 inches, direct coupled to 400 kilowatts Siemens and Halske outside field generators. *Station E.*—This is at Birmingham, 18 miles from the City Hall, and contains one Babcock and Wilcox 250-HP. boiler, with Roney stoker, and three fire-tube boilers of 125 HP., each hand fired. There are two Westinghouse compound condensing engines, 16 and 30 by 18 inches, belted to 250 kilowatts Westinghouse generators. *Station F.*—This is at Pontiac, 26 miles from the City Hall, and is only used in case of emergency. It contains two Phœnix Iron Works 100 HP. boilers, one 16 by 15 inches Dick and Church engine, and one 15 by 16 inches Ball engine, each belted to 100 kilowatts Westinghouse generators. *Station G.*—This

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is at Rochester, 28 miles from the City Hall. It contains four 250 HP. Aultman and Taylor boilers. There are two 325 HP. Ball and Wood horizontal tandem compound condensing engines, 15 and 30 by 16 inches, direct connected to Crocker-Wheeler 200 kilowatts generators, and a 21½ and 45 by 20 inches Ball and Wood vertical cross-compound condensing engine, direct connected to a Crocker-Wheeler 400 kilowatts generator. There is a motor-generator set for local lighting, a booster for the distant part of the line, and a 250 kilowatts rotary converter with step-up transformers, feeding at 15,000 volts through lines 13 miles and 30 miles long to the Oxford and Atlas sub-stations, where are step-down transformers and rotary converters. *Station H.*—This is a battery station, situated on an equaliser connected to the various feeders, about 3½ miles from stations H and B. It contains a battery of 250 chloride cells, having each 52 plates with a discharge capacity of 2,000 amperes at 500 volts for 1 hour, 1,000 amperes for 3 hours, or 500 amperes for 8 hours. *Station I.*—This is a battery station at Ecorse, about 10½ miles from the power-house. It contains 276 chloride cells, type F-15. It has a discharge capacity of 280 amperes for 1 hour.

A. E. L.

Electrical Equipment of the Consolidated California and Virginia Mining Company, Nevada. L. M. Hall.

(Elect. Review, New York, 41, pp. 298–302, September 6, 1902.)

This paper describes a very large and important plant for transmitting and utilising power in mining operations. The generating plant consists of two 1,400 HP. turbines working with a head of 85 feet. These drive three-phase 60 ∾ revolving armature generators with 22 kilowatts exciters. The current is generated at 500 volts, transformed by oil-insulated transformers to 24,000 volts, and conveyed 33 miles by bare wire on 7½ inches Locke insulators supported on pine cross-arms on 30 feet redwood poles. At Virginia City the pressure is lowered to 2,300 volts and distributed to the mining companies. The charge is $7 per HP. per month gauged upon a two-minute maximum demand. A large consumption of power takes place at the mine in question. The largest motors are a 200 HP. variable speed induction motor working a hoist, a 100 HP. ditto making an air compressor, three 225 HP. working Riedler pumps underground, besides many smaller ones, and lighting the plant is by Westinghouse. The cost of power locally is $28 per HP. month, so the electric power only cost one-fourth that of the power generated locally.

Ll. B. A.

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INDEX

TO THE

MINUTES OF PROCEEDINGS,

1902–1903.—PART II.

N.B.—Titles in italics refer to Original Papers, and those selected for printing only are further distinguished by the suffix "(S.)" or "(St.)," the latter denoting Students' Papers. Abstracted Papers are not so indicated.

Accumulator traction on heavy railways, 354.
Accumulators. Storage batteries for electric automobiles, 6 *et seq.*
Adams, B. K., elected associate member, 2.
Addison, J., memoir of, 315.
Ader light automobile, 406.
Air, compressed, use of caissons with, for extending river-piers, 359.
Aird, Sir J., Bart.—*Discussion on the Nile Reservoir and Sluices:* Wisdom of the engineers in insisting on the foundations being carried down to sound rock, 124; amicable relations between engineers and contractors throughout, 125; nature of the stone used for the dam, 125; the workmen employed, 125; obligations of the contractors to their staff, 126; rapid execution of the sluices by Messrs. Ransomes and Rapier, 126; appreciation of the labours of the executive engineers, 127.
Airship, Barton's, 407.
Alcohol motors, stationary, the phenomena of combustion in, 367.
Allen, G. J., admitted student, 1.
——, H. G., B.A., elected associate member, 2.
Alternators, the parallel operation of, 404.
Andoe, H. B., admitted student, 156.
Arnold, B. J., electro-pneumatic railway system, 412.
—— ——, relative cost of steam and electric railway operation, 414.
Ashforth, G. E., M.Sc., elected associate member, 156.
Asphalt.—"*Recent Developments of the Asphalt Industry*," W. H. Delano (S.), 258.
—— refining, 371.

Digitized by Google

Automobile, Chenard-Walcker motor-carriage, 405.
————, Ader light, 406.
Automobiles. Daimler cars, 407.
————. Electric-accumulator traction on heavy railways, 354.
————.—"*Electric Automobiles*," H. F. Joel, 2.—Advantages, in point of economy and convenience, possessed by motor-cars, 2.—Automobile manufacture on the Continent, 3; weights of the earlier electric carriages and of their batteries, 3; progress made during the years 1896–1901, 4; recent examples of long-distance runs, 4; results of official trials of electric carriages, 5.—Storage batteries, 6; battery-tests made by the Automobile Club of France, 1899, 11.—Electric motors and gears, 11.—Controllers and circuits, 15.—Underframes, 20.—Design and construction, 23.—Ratio of power to load, 27.—Cost of propulsion, 30; comparison of the results attained by electric automobiles and those by electric railways, 31.—*Appendix:* Table I. Particulars of early and recent electric vehicles, 33; Table II. Five years' progress in electric automobiles, 33; Table III. Long runs in one charge, 34; Table IV. Results of some official tests, 36; Table V. Working costs of various methods of propulsion for vehicles, 38.—*Discussion:* J. C. Hawkshaw, President, 40; H. F. Joel, 40; A. B. Chatwood, 43; Prof. W. E. Ayrton, 44, 56; T. Clarkson, 50; Col. R. E. B. Crompton, 53; P. W. Northey, 57; L. H. Rugg, 59, 60; W. W. Beaumont, 59; B. Drake, 60; A. B. W. Kennedy, 62; Sir F. J. Bramwell, Bart., 62; H. F. Joel, 63.—*Correspondence:* H. L. Joly, 64; J. N. Shoolbred, 67; H. F. Joel, 69.
————, stability of, on curves, 397.
————, steam, braking-power of the compression in, 52.
Ayrton, W. E.—*Discussion on Electric Automobiles:* Optimism of the Author's views of the possibilities of electric vehicles, 44; storage capacity of cells in actual practice, 44; experiments on charging cells at constant potential difference, 45; cell devised by Mr. Fithian, 46; deterioration of efficiency of accumulators, 47; actual consumption of energy per ton-mile by the vehicles of the London Electric Cab Company, 47; experiments on the tractive resistance to vehicles with pneumatic tires, 48; reason of the failure of the London Electric Cab Company, 48; importance of not allowing the voltage to fall below 1·8 volt on discharging, 50; comparative working costs of electric and other automobiles, 56.

Bach, C., heating-value of superheated steam, 360.
Bacon, F., jun., admitted student, 1.
Baker, Sir B.—*Discussion on the Nile Reservoir and Sluices:* Work of British engineers in Egypt, 133; the Assuan dam its first impressive result, 134; part played by engineers in the development of Egypt, 135; capacity of the engineer for the administration of large undertakings, 135; good fortune experienced in getting in the foundations, 135; appreciation of the work of the engineers, 137.
———, J. A., admitted student, 1.
———, L. A., admitted student, 1.
Baldwin, A. E., memoir of, 336.
Bancroft, F. H., elected associate member, 2.
Barr, T. M., memoir of, 317.

Digitized by Google

Barrus, G. H., tests of steam-pipe coverings, 416.
Barton, W. C., memoir of, 318.
Barton's airship, 407.
Batchen, T. M., transferred member, 1.
Batteries, storage. See Accumulators.
Beard, S. R. H., elected associate member, 2.
Beaumont, W. W.—*Discussion on Electric Automobiles:* Tractive resistance to omnibuses on asphalt roads, 59.
Beesley, W., transferred member, 1.
Behn-Eschenburg, Dr., variable-speed polyphase and direct current motors, 381.
Bellet, D., the Paris cold-storage depot, 378.
Bellingham, A. W. H., transferred member, 1.
Benedict, E.—*Discussion on the Nile Reservoir and Sluices:* Sanitary arrangements for large undertakings in tropical countries, 127.
Berrington, R. E. W., transferred member, 1.
Bindloss, E. A. M., elected associate member, 156.
Binnie, W. J. E.—*Correspondence on the Nile Reservoir and Sluices:* Datum of the levels used in the plans, 140.
Black, J. F., B.Sc., elected associate member, 2.
Blast-furnace slag, the conversion of, into iron-Portland cement, 389.
Bonnin, R., metallic lattice-girder bridges, with flexible connections, 357.
Boor, F. de, the production of power by means of small motors, 363.
Borries, von, tests of locomotive performance, 352.
Bourne, T. J.—"*The Construction of the Lu-Pao District of the Lu Han Railway,*" (S.), 157.
Bowen, S., admitted student, 156.
Brakes for tramcars, 423.
Bramwell, Sir F. J., Bart.—*Discussion on Electric Automobiles:* Cost of keeping a pair-horse landau in London, 62.
Breüer, K. A., the Bex-Gryon Villars, and Aigle-Leysin mountain railways, Switzerland, 345.
Bridge, bascule, at the Nile reservoir, Assuan, 117.
——— piers. See Piers.
Bridges and flood-openings on the Lu-Han railway, 165 *et seq.*
———, lattice-girders, metallic, with flexible connections, 357.
———, recently built across the lower Rhine, 205.
Brown, J. W., transferred member, 156.
———, Sir R. H.—*Correspondence on the Nile Reservoir and Sluices:* The Nile flood in Egypt below the reservoir unaffected by the construction of the dam, 141; account of the first filling operations, 141.
Browne, B. C., jun., elected associate member, 156.
Bruce, R.—"*Notes on the Construction of the Permanent Way of Electric Tramways,*" (St.), 285.
Bruck, lubrication with graphite for locomotives, 353.
Bush, R., B.A., transferred member, 156.

Caissons, use of, with compressed air, for extending river-piers, 359.
Campbell, D. W., C.I.E., memoir of, 319.
Canal, Dortmund-Ems, 214.

Digitized by Google

Canal, Elbe-Trave, 229.
———, Kaiser-Wilhelm, 222.
———, North Sea, electrically operated plant on the, 409.
———, Soulanges, electric plant, 419.
———lift, floating, Henrichenburg, 215.
Candlot, E., the Portland cement industry, 388.
Cardew, J. H.—"*Burraga Dam and Water-Supply for the Lloyd Copper Company's Mine, New South Wales*," (S.), 237.
Carew-Gibson, H. F.—*Correspondence on the Nile Reservoir and Sluices*: Surface-gradient of the full reservoir, 142; setting-out of the work, 142; burnt clay and lime-mortar, 142; difficulty experienced in keeping the green masonry well watered, 143.
Castle, H. J., memoir of, 339.
Cavitation, 373.
Cay, W. D.—*Correspondence on the Nile Reservoir and Sluices*: Loss from evaporation in conveying the water from the reservoir to the irrigated land, 143; tables of rainfall and evaporation at ten stations in Egypt, 144.
Cement, Portland, industry, 388.
———, ———, iron-, the conversion of blast-furnace slag into, 389.
Chatwood, A. B.—*Discussion on Electric Automobiles*: Electric lorries for carrying cotton, 43; connection between motors and underframes and between front and back wheels, 43.
Chenard-Walcker motor-carriage, 405.
Chimneys, tall, strength of, 378.
Clark, J. M., elected associate member, 156.
Clarke, W. J., admitted student, 1.
Clarkson, T.—*Discussion on Electric Automobiles*: Optimism of the Author's views of the possibilities of electric vehicles, 50; comparison of electric with petrol and steam carriages under like conditions, for touring purposes, 51; braking power of the compression in steam cars, 52; inherent disadvantages of lead cells, 52; comparative cost of running steam and electric cars, 53.
Clays, the plasticity of, 386.
Clemes, J. H., transferred member, 1.
Coffer-dams used in the construction of the dry dock at Riley's Hill, Richmond River, N.S.W., 192.
Cold-storage depôt, Paris, 378.
Cook, W. E.—"*Erection of the Nairne Viaducts, near Adelaide, Australia*," (S.), 185.
Concrete, notes on, 172.
———, reinforced. See Ferro-concrete.
Contal-Gasnier motor for electric automobiles, 65.
Cotton, C. G., admitted student, 1.
Craig, A. D.—"*Dry Dock at Riley's Hill on the Richmond River, New South Wales*," (S.), 188.
Crane, W. R., asphalt refining, 371.
Crane, floating, 25-ton, for the works of the port of Ceuta, 359.
Cranes in the port of Hamburg, 234.
Crompton, Col. R. E. B.—*Discussion on Electric Automobiles*: Advantages of electric vehicles for use by unskilled persons and in towns, 53; causes of the failure of the London Electric Cab Company, 54; importance of the electric automobile to electric lighting stations, 54; possibility of successful working

Digitized by Google

of electric vehicles with proper organization of the charging and repairing arrangements, 54; incorrectness of some of the Author's figures for the energy-consumption of electric automobiles, 55; influence of the size of wheels on tractive resistance, 56; comparative working costs of electric and other automobiles, 57.
Cullen, E. A., transferred member, 1.
Curtis. See Moultrop.
Cusack, R. S. O., elected associate member, 156.
Cylinder-supports of vertical engines, strength of, 369.

Daimler cars, 407.
Dam, Assuan. See Reservoir.
——, "*Burraga Dam and Water-Supply for the Lloyd Copper Company's Mine, New South Wales*," J. H. Cardew (S.), 237.—Catchment-area, 238; rainfall, 238; capacity of reservoir, 238; yield of gathering-ground, 238; trial pits, 239; design of dam for the impounding-reservoir, 241; construction, 243; stopping a leak, 245; pipe-line, 247; cost, 248.
Dams, temporary, in the River Weaver, use of sand for forming, 150.
Dankwardt, Siemens and Halske's improvements in telephone exchanges, 384.
David, C. J. E., B.A., admitted student, 156.
Davidson, W. R., admitted student, 1.
Davies, I. P., admitted student, 1.
———, St. J. A., admitted student, 1.
Davis, C. H., competition of steam and electric railways, 400.
———, W. J., jun., train-resistance, 411.
Delano, W. H.—"*Recent developments of the Asphalt Industry*" (S), 258.
Denison, A., transferred member, 1.
Destructors. See Refuse disposal.
Diatto surface-contact system, 401.
Docks.—"*Dry Dock at Riley's Hill on the Richmond River, New South Wales*," A. D. Craig (S.), 188.—General, 188; description of the dock, 189; construction, 191; coffer-dam, 192; emergency coffer-dam, 194.
——, graving, concrete, in Kiel harbour, 227.
Dodson, C. S., admitted student, 1.
Drake, B.—*Discussion on Electric Automobiles*: Development of accumulator traction in New York, 60; batteries in general use in America, 60; ease of varying the speed of an electric car, 61; systems of charging cells, 61; weight of accumulators, 61.
Dredging in the Kaiser-Wilhelm canal at Brunsbüttel, 224.
Dry-rot, 392.
Duff, W. A., memoir of, 337.
Dussaugey, protection of electric transmission lines against lightning, 427.
Dyer, A. R., elected associate member, 2.

Egerton, C. F. A., transferred member, 1.
Electric automobiles. See Automobiles.
———- power in the iron and steel industries, 427.

Digitized by Google

Electric power-transmission.—"*The Cauvery Power-Transmission Scheme*," H. T. Hincks (S.), 269.—General, 269; the River Cauvery, 270; canals, 271; penstocks, 271.—Generator-station, 272; turbines, 272; generators, 273; exciters, 274; switchboards, 274.—Masonry conduit, 274.—Step-up transformer-station, 274; low-tension and exciter switchboard, 275; transformers, 275; high-tension switchboard, 276.—Lightning arresters, 276; transmission line, 276; telephone, 278; step-down transformer-station, 278; distribution-tower, 279; main feeder-lines, 279; mine plant, 280; work done, 280; load, 282; total efficiency of plant, 282; agreement, 282; cost, 283.
——— railways. See Railways.
——— tramways. See Tramways.
——— transmission lines, protection of, against lightning, 427.
——— ——— ———. Insulated lines in India, 418.
Electrical machinery, standardizing, 408.
Electricity in iron and steel works, 426, 427.
——— station. The water and electrical power system of the Pike's Peak Power Company, Colorado, 380.
——— ——— of the Edison Company, Boston, 420.
——— ———, water-power, at Burgos (Spain), 379.
——— ———. Concord, N.H., water-power plant, 421.
——— stations of the Detroit United railway, 429.
——— ———. Water-power in Ireland, 420.
Electrolysis, alternate-current, 396.
Engines, vertical, strength of cylinder-supports of, 360.
———. See also Motors.
Etheridge, H. O. H., admitted student, 1.
Evaporation and rainfall in Egypt, 144, 151.

Farmer, T., Detroit United railway power-stations, 429.
Ferro-concrete constructions, the tensile strength and deflection of, 391.
Fischer, H., a new method of heating buildings, 377.
Fitzmaurice, M.—"*The Nile Reservoir, Assuan*," 71.—*Discussion:* Necessity of carrying the foundations down to sound rock, 138; causes of the early completion of the work, 138; sanitary arrangements, 138: tests of lime and clay mortar, 138; difference between estimated and actual cost, 138; silt in the Nile water during filling, 138.—*Correspondence:* Datum of the levels used, 151; discharge of the Nile in flood not affected by the construction of the dam, 151; evaporation in Egypt, 151; cost of the work, 152; construction of the sudds, 152; discharge of the Nile at different gauge-levels, 152; reasons for not adopting larger sluices, 152; necessity for a masonry apron below the high-level sluices, 153; reason for not adopting culverts in the lock-walls, 154.
Ford, J. T.—*Correspondence on the Nile Reservoir and Sluices:* Cost of the work, 146.
Fournier, L., Ader light automobile, 406.
Fox, W. E., B.E., admitted student, 156.
Frahm, H., torsional stress in the connection between the ship's engines and the propeller, 416.
Fuel, liquid, combustion of, 417.
——, pulverised, for power plants, 397.

Digitized by Google

Gale, W. M., transferred member, 156.
Gasche, F. G., pulverized fuel for power plants, 397.
Gas-engine research, 364.
————, three-cylinder compound, 366.
——-engines, heat balance of, 366.
Gavey, G. E., memoir of, 320.
Gaze, M., electric locomotive for rack and adhesion railway, 402.
Gearing. Efficiency of modern worm-gearing, 57; Lanchester worm-gearing, 59
Geen, G. P., admitted student, 1.
Gerard, L., electric railways, 400.
Gola's lightning arresters, 425.
Gold-fields, Kolar, India, electric power-transmission from the Cauvery Falls to the, 269.
Gostkowski, R., economical speed of goods trains, 352.
Graphite, lubrication with, for locomotives, 353.
Greig, B. W. P., elected associate member, 2.
Gribble, T. G., transferred member, 1.
Griffith, N. R., memoir of, 322.
Güldner, H., design of internal-combustion motors, 363.

Hall, L. M., electrical equipment of the Consolidated California and Virginia Mining Company, Nevada, 430.
Hanson, E. B., memoir of, 322.
Harding, W. J., elected member, 156.
Hardesty, W. P., the water and electrical power system of the Pike's Peak Power Company, Colorado, 380.
Hardisty, J., elected member, 2.
Harmet process for the production of steel direct from the ore, 403.
Harrison, G. D., transferred member, 156.
————, J. F., transferred member, 1.
Hawkshaw, J. C., President.—*Discussion on Electric Automobiles:* Remarks in proposing a vote of thanks to the Author, 40.—*Discussion on the Nile Reservoir and Sluices:* Remarks in proposing a vote of thanks to the Authors, 124.—Ditto in announcing the death of Sir George Stokes, 155.
Hawksley, K. P., transferred member, 1.
Heating buildings, a new method of, 377.
Hewitt, A. S., memoir of, 340.
Hillman, C. la F., memoir of, 323.
Hincks, H. T.—"*The Cauvery Power-Transmission Scheme*," (S.), 269.
Hindley, O. W., B.A., elected associate member, 2.
Holland, T. H., mica-mining in India, 372.
Horn, W. R., admitted student, 1.
Horwood, C. B., elected associate member, 156.
Hoskold, H. D., transit theodolite for mining engineers, 403.
Howden, T. M., memoir of, 338.
Hydro-electric power. See Electricity station.

Induction motors, effect of closed slots in stator-cores of, 427.
Insulated lines in India, 418.

Digitized by Google

Iron and steel industries, electric power in the, 427.
—— —— —— works, electricity in, 426.
Irrigation, Egyptian, 71 *et seq.*

Jantzen, the conversion of blast-furnace slag into iron-Portland cement, 389.
Jenkins, W. R., admitted student, 1.
Joel, H. F.—"*Electric Automobiles*," 2.—*Discussion:* Description of the "sine" motor, 40; comparative working costs of horse-drawn and electric mail-coaches, 41; comparative consumption of energy per ton-mile by electric automobiles and electric railways, 42; reduction recently effected in the weight of batteries, 42; deterioration of efficiency of cells on discharge, 63; justification for the data given in the Paper, 63.—*Correspondence:* Energy consumption of electric vehicles per ton-mile, 69; storage capacity of cells, 69; working-costs of different vehicles, 69.
Johnston, C., elected associate member, 2.
Joly, H. L.—*Correspondence on Electric Automobiles:* Drawbacks to the zinc-lead peroxide cell, 64; tests made by the Automobile Club of France, 64; influence of rate of discharge on the capacity and the average voltage, 64; capacity of a cell made by Faure in 1886, 65; Contal-Gasnier motor, 65; raising the potential difference the real advantage of recuperation, 65; consumption of energy per ton-mile according to Kallmann, Joel, Fliess and Muhlberg, 65; charging from alternating-current stations, 66; unreliability of some of the Author's figures for working-costs, 66; working-costs of electric vehicles according to various French authorities, 66; financial results of services of public electric vehicles in the United States, 67; value of the electric automobile to central stations, 67.
Jones, E. L. H., elected associate member, 2.
Julius, C. H., the Diatto surface-contact system, 401.

Keay, W. G., elected associate member, 2.
Kennedy, Dr. A. B. W.—*Discussion on Electric Automobiles:* Usefulness of electric vehicles for town work, 62; cost of running an electric vehicle, 62.
Ker, H. T., transferred member, 1.
Kharegat, M. M. R., elected associate member, 156.
King, H. C., tractive effort and power of tramway motors, 402.
Kingsbury, P. C., admitted student, 156.
Kite, F. W., elected member, 2.
Küster, F. W., P. Siedler and A. Thiel, testing hard-lead, 386.
Kylberg, F., electricity in iron and steel works, 426.

Laboratory, hydraulic, of the technical high school at Karlsruhe, 333.
Lang. See Preuss.
Lead, hard-, testing, 386.
Le Chatelier, H., the permeability of mortars, 388.
Lecuir, high-speed pumps, 361.
Le Lievre, C., memoir of, 324.
Lightning arresters, Gola's, 425.
———— ———— on the Cauvery Falls power-transmission line, 276.

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Lightning, protection of electric transmission lines against, 427.
Liquid fuel combustion, 417.
Little, M., elected associate member, 156.
Lloyd, G. B., memoir of, 343.
Lock-gates of the Nile reservoir, Assuan. See Reservoir.
Locks on the Elbe-Trave canal, 230.
——— — — Kaiser-Wilhelm canal, at Brunsbüttel and Holtenau, 223.
———, Ymuiden (North Sea Canal), electrical operation of the, 409.
Locomotive, electric, for rack and adhesion railway, 402.
——————— performance, tests of, 352.
Locomotives and rolling stock on the Eastern railway of France, 347.
——————, lubrication with graphite for, 353.
London Electric Cab Company, consumption of energy per ton-mile by the vehicles of the, 47; causes of the failure of the, 48, 54.
Longwell, H. E., the parallel operation of alternators, 404.
Lorries, electric, for carrying cotton, 43.
Lubrication with graphite for locomotives, 353.
Lucke, C. E., liquid fuel combustion, 417.

McComas, H., B.A.I., admitted student, 156.
MacGregor, R. M., admitted student, 1.
Mackail, G. H., elected member, 2.
Macnie, J., memoir of, 338.
Mail-coaches, horse-drawn and electric, comparative working costs of, 41.
Malenkovic, dry-rot, 392.
Mann, G. O., memoir of, 325.
Marrian, A. E.—*Correspondence on the Nile Reservoir and Sluices:* Work done per man per hour on the sudds, 146; composition of the granite used in construction, 146; trial borings in the bed of the river, 146.
Marsh, H. E., admitted student, 156.
Marshall, F. C., memoir of, 326.
Mason, A. S., admitted student, 1.
Mathews, E. G. D., admitted student, 156.
Maughan, N., elected associate member, 156.
May, C. R., transferred member, 1.
———, W., transferred member, 1.
Merrill, F. E., Detroit, Ypsilanti, Ann Arbor and Jackson railway, 428.
Meyer, E., gas-engine research, 364.
———, G. W., high-speed electric railways, 399.
Mica-mining in India, 372.
Mining Company, Consolidated California and Virginia (Nevada), electrical equipment of the, 430.
——— engineers, transit theodolite for, 403.
——— machinery of the Kolar gold-fields India, electric operation of the, 269.
Mollier, W., effect of closed slots in stator-cores of induction motors, 427.
Mortar, lime and clay, used in the construction of the Assuan dam, 107, 132, 138.
Mortars, the permeability of, 388.
Moser, F. W. F., admitted student, 1.
Motor, Contal-Gasnier, for electric automobiles, 65.
———, "sine," for electric automobiles, 40.

Digitized by Google

Motor-cars. See Automobiles.
Motors, alcohol, stationary, the phenomena of combustion in, 367.
———, electric, and gears for electric automobiles, 11 *et seq.*
———, ———, driven by petrol engines, possibilities of, 59.
———, internal-combustion, design of, 363.
———, small (cost of) production of power by means of, 363.
———, tramway, tractive effort and power of, 402.
———, variable-speed polyphase and direct-current, 381.
———. See also Engines.
Moultrop, I. E., and R. E. Curtis, the Edison Company's station, Boston, 420.
Mountain railways. See Railways.
Mühlmann, electric-accumulator traction on heavy railways, 354.
Municipal engineering.—"*Notes upon Municipal Work in Sydney, New South Wales,*" R. W. Richards (S.), 251.—Street construction, 253; disposal of refuse, 256.

Navigation.—"*The Düsseldorf Navigation Congress*, 1902; *and Works visited by the Congress in Germany,*" L. F. Vernon-Harcourt (S.), 196.—The Congress, 196.—The Lower Rhine and its ports in Germany, 200.—Elberfeld and Barmen suspended railway, 206.—Dortmund-Ems canal, 214.—The River Weser and the ports of Bremen and Bremerhaven, 220.—Kaiser-Wilhelm canal, 222.—Concrete graving-docks in Kiel harbour, 227.—The Elbe-Trave canal, 229.—The port of Hamburg, 232.
Nichols, H. B., transferred member, 1.
Normand, J. A., cavitation, 373.
Northey, P. W.—*Discussion on Electric Automobiles:* Use of porous pots in zinc-lead peroxide cells, 57; high efficiency of modern worm-gearing, 57; shunt wound *versus* series-wound motors, 58; advantages of double-wound armatures, 58; possibilities of electric motors driven by petrol engines, 59; indicating the attainment of the limiting potential difference in discharging cells, 59.
Nys, L. de, rolling platforms for extension of wayside stations, 356.

Oldham, R. A., memoir of, 328.
Omnibuses, London, results of experiments on tractive resistance to, 59.
Ostenfeld, Prof. A., strength of struts, 385.
Ozone, further experiments with, for water-purification, 375.

Parker, O. F., B.A., admitted student, 156.
Pearson, J. D., B.A., B.E., elected associate member, 156.
Peat charcoal, manufacture of, 369.
Permanent way of electric tramways. See Tramways.
Petot, A., stability of automobiles on curves, 397.
Piers, river-, use of caissons with compressed air for extending, 359.
Pipe, steam-, coverings, tests of, 416.
Platforms, rolling, for extension of wayside stations, 356.
Pledge, M. F. de, transferred member, 1.
Port of Hamburg, 232.

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Ports of Bremen and Bremerhaven, 221.
——— — the lower Rhine in Germany, 200.
Power, (cost of) production of, by means of small motors, 363.
——— plants, pulverized fuel for, 397.
——— stations. See Electricity stations.
Preuss and Lang, strength of tall chimneys, 378.
Price, J.—*Correspondence on the Nile Reservoir and Sluices:* Comparison of the Assuan sluices with those erected at Belleek, Lough Erne, in 1883, 147; sluices without rollers at R.L. 92, 148; small size of the Assuan sluices, 148.
Propeller cavitation, 373.
———, pendulum-, trials, 372.
Propellers. Torsional stress in the connection between the ship's engines and the propeller, 416.
Proskauer and Schüder, further experiments with ozone for water-purification, 375.
Pryde, J., transferred member, 1.
Puller, a new tachymeter, 368.
Pumps, high-speed, 361.

Railway curves. The transition spiral, 401.
———, Detroit United, power-stations of the, 429.
———, Detroit, Ypsilanti, Ann Arbor and Jackson, 428.
———, Eastern of France, locomotives and rolling stock on the, 347.
———, Gellivare Northern, the, 346.
——— grades and alignment, determination of, 415.
———, rack and adhesion, electric locomotive for, 402.
——— rolling stock. Locomotives and rolling-stock on the Eastern railway of France, 347.
——— — ———. New passenger carriages on the Bavarian State railways, 350.
——— signalling. See Signalling.
——— stations. See Stations.
———, street. See Tramway.
———, suspended, Elberfeld and Barmen, 206.
——— system, electro-pneumatic, 412.
Railways, Bavarian State, new passenger carriages on the, 350.
———, electric, 400.
———, ———, and electric automobiles, comparison of results attained by, 31, 42.
———, ———, high-speed, 399.
———, ———, the Fayet-Chamonix, 410.
———, ———. The Zossen-Marienfelde polyphase railway trials, 398.
———, heavy, electric-accumulator traction on, 354.
———, mountain, the Bex-Gryon-Villars and Aigle-Leysin, Switzerland, 345.
———, steam and electric, competition of, 400.
———, ——— — ———, relative cost of operation of, 414.
Railways. "*The Construction of the Lu-Pao District of the Lu-Han Railway,*" (S.), 157.—Historical, 157; general character of the country, 159; preliminary survey, 160; location, 161; earthwork, 162; branch line for supplies, 164.—

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Railways—*continued.*
Bridges and flood-openings, 165; foundations, 168; concrete masonry, 170; shuttering, 173; protection of bridges, 174; erection of girders, 175.—System of construction, 176; rails and rail-laying, 177; ballasting, 178; stations and buildings, 179; rolling stock, 180; traffic, 180; workshops, 182; cost of the work, 182.—*Appendix*, 184.
Rainfall and evaporation in Egypt, 144, 151.
Rampal, L. F., admitted student, 1.
Rampal, L. M., admitted student, 1.
Ramsey, A. N., elected associate member, 2.
Reeve, H., C.M.G., transferred member, 1.
Reeves, R. E., elected associate member, 2.
Refrigeration. The Paris cold-storage depot, 378.
Refuse disposal in Sydney, 256.—The garbage furnaces of Trenton, N.J., 423.
Rehbock, Prof. T., hydraulic laboratory of the technical high school at Karlsruhe, 393.
Rendel, H. W., transferred member, 156.
Renton, A. C., transferred member, 1.
Reservoir. "*The Nile Reservoir, Assuan,*" M. Fitzmaurice, 71.—The Nile and Egyptian irrigation, 71.—History of the project, 73.—Geological conditions, 77.—Description of the reservoir, 78.—Preliminary work, 84.—Description of the dam, 87.—Temporary dams, 92.—Building masonry, 96.—Locks and navigation channel, 101.—Temple of Philae, 103.—Conclusion: quantities and cost, 104.—*Appendix:* Result of long-time tests of lime and clay mortar, 107.
——— "*Sluices and Lock-Gates of the Nile Reservoir, Assuan,*" F. W. S. Stokes, 108.—General description: the Stoney sluice, 108, 109.—Sluices at R.L. 100 and R.L. 96, 110.—Sluices at R.L., 92: with rollers, 112, without rollers, 112.—Sluices at R.L. 87·50, 113.—Culvert-linings, 113.—Lock-gates, 114.—Bascule bridge, 117.—General equipment, 117.—Cataract lock, 118.—Erection of the work, 119.—*Discussion on the two preceding Papers:* J. C. Hawkshaw, President, 124; Sir J. Aird, Bart., 124; E. Benedict, 127; F. E. Robertson, 127; L. F. Vernon-Harcourt, 128; F. R. Upcott, 132; Sir B. Baker, 133; M. Fitzmaurice, 138; F. W. S. Stokes, 138.—*Correspondence:* W. J. E. Binnie, 140; Sir R. H. Brown, 140; H. F. Carew-Gibson, 142; W. D. Cay, 143; J. T. Ford, 146; A. E. Marrian, 146; J. Price, 147; H. Siccama, 148; L. B. Wells, 149; M. Fitzmaurice, 151; F. W. S. Stokes, 154.
Rich, T., elected associate member, 2.
Richards, R. W.—"*Notes upon Municipal Work in Sydney, New South Wales,*" (S.), 251.
River Cauvery power-transmission scheme. See Electric power-transmission.
——— Nile. See Reservoir.
——— Rhine. The lower Rhine and its ports in Germany, 200.
——— Weser, improvement of the, 220.
Robb, W. L., tests of steam turbine at Hartford, Conn., 423.
Roberts, F. W. C., admitted student, 1.
Robertson, F. E.—*Discussion on the Nile Reservoir and Sluices:* Liability to occasional floods in "rainless" countries, 127; sanitary arrangements in hot countries, 128.
Robins, C., memoir of, 330.
Rogers, T. H. G., elected member, 2.
Rosher, E. M., elected associate member, 2.

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Rugg, L. H.—*Discussion on Electric Automobiles:* Lanchester worm-gearing, 59; results of experiments on tractive resistance to London omnibuses, 59, 60.
Rühl, telephone conduits, 403.
——, telephone cable-conduits with single ways, 383.

Salomon, L., locomotives and rolling stock on the Eastern railway of France, 347.
Samuelson, M., memoir of, 331.
Sand, use of, for forming temporary dams in the River Weaver, 150.
Sanitary arrangements for large undertakings in tropical countries, 127, 128, 138.
Schäfer, C. P., new passenger carriages, 350.
Schnatter, J., point-lock with electric release, 355.
Schröder, R., Hamburg waterworks, 375.
Schüder. See Proskauer.
Schule, F., the tensile strength and deflection of ferro-concrete constructions, 391.
Schwarz, G., strength of cylinder-supports of vertical engines, 360.
Scott-Moncrieff, K. A., insulated lines in India, 418.
Selby-Bigge, D., electric power in the iron and steel industries, 427.
Shaw, C. W., admitted student, 1.
Shepherd, J., elected associate member, 2.
Shoolbred, J. N.—*Correspondence on Electric Automobiles:* Need for improved batteries and extended facilities for charging, 67; advantages of extending the applications of electric power, 68; direct transport of goods from the docks at Liverpool by means of electric vehicles, 68.
Siccama, H.—*Correspondence on the Nile Reservoir and Sluices:* Omission of an apron on the down-stream side, and of a side weir, 149; cost of the work, 149; conveyance of pressure-water across the locks, 149; horizontal section of both gates, 149; valves in the gates *versus* culverts in the lock-walls, 149.
Siedler. See Küster.
Siemens and Halske's improvements in telephone exchanges, 384.
Signalling, lock-and-block, with no releasing key, 355.
————. Point-lock with electric release, 355.
————. Treadles for single-line railway, 351.
Simmons, Field-Marshal Sir J. L. A., memoir of, 312.
"Sine" motor, description of the, 40.
Slag. See Blast-furnace slag.
Sluices, Assuan. See Reservoir.
——, Belleek, Lough Erne, 147, 154.
——, Dutton, 150.
Smith, V. C., admitted student, 156.
Smithe, E. du C., elected member, 156.
Sorel, on the phenomena of combustion in stationary alcohol motors, 367.
Spencer, C. J., brakes for tramcars, 423.
Spiral, the transition, 401.
Staircase with right and left treads, 358.
Standen, H. W., elected associate member, 156.
Stanford, F. O., elected associate member, 156.
Stations, wayside, rolling platforms for extension of, 356.
Staus A., heat-balance of gas-engines, 366.

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Steam-pipe coverings, tests of, 416.
———, superheated, heating-value of, 360.
Steel, Harmet process for the production of, direct from the ore, 403.
——. See also Iron and steel.
Steinle, construction of thermometers, 395.
Stewart, F. R., B.Sc., admitted student, 156.
Stokes, F. W. S., transferred member, 1.—"*Sluices and Lock-Gates of the Nile Reservoir, Assuan*," 108.—*Discussion:* Principles of action of the Stoney sluice, 139.—*Correspondence:* Differences between Assuan and Belleek sluices, 154; sluices without rollers at R.L. 92, 154; conveyance of pressure-water across the locks, 154; bascule bridge across the locks, 154; reason for not adopting culverts in the lock-walls, 154; satisfactory working of the valves in the gates in regard to freedom from mud deposits and safety in locking vessels, 155.
———, Sir G. G., Bart., announcement of death of, 155.
Stoney sluice, the, 109 *et seq.*
Street construction in Sydney, 253.
——— railway. See Tramway.
Struts, strength of, 385.
Sudd construction at the Nile reservoir, Assuan, 152.
Surface-contact system, the Diatto, 401.

Tachymeter, a new, 368.
Tatlow, W., water-power in Ireland, 420.
Taylor, W. J., transferred member, 1.
Telephone cable-conduits with single ways, 383.
————-cables, German, changes in the construction of, 383.
———— conduits, 403.
———— exchanges, Siemens and Halske's improvements in, 384.
Temple of Philae, Egypt, effect of the construction of the Assuan dam upon the, 103.
Teredo, damage done by, to coffer-dam at Riley's Hill dry dock, Richmond River, N.S.W., 193.
Theodolite, transit, for mining engineers, 403.
Thermometers, construction of, 395.
Thiel. See Küster.
Thomas, R. E., admitted student, 1.
Timber, dry-rot in, 392.
Tires, pneumatic, experiments on the tractive resistance to vehicles with, 48.
Torrance, W. M., the transition spiral, 401.
Train-resistance, 411.
Trains, goods, economical speed of, 352.
Tramcars, brakes for, 423.
Tramway. The Bremgarten-Dietikon electric street railway, 357.
———— motors, tractive effort and power of, 402.
Tramways, electric.—"*Notes on the Construction of the Permanent Way of Electric Tramways*," R. Bruce (St.), 285.—Rails, 285; drain rails, 290; rail-joints, 290; welded joints, 295; tie-bars, bolts and nuts, 296; points, 296; crossings, 297; heel-plates, 298; passing-places, cross-overs, etc., 299; excavation, 300; con-

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Tramways, electric—*continued.*
crete foundations, 300; platelaying, 301; bonding, 303; plastering rails, 305 paving, 305; grouting, 307; estimate of the cost of construction per mile of single track, 307.—*Appendix*, 309.
Transformer, rotary, 150-HP. polyphase direct, 382.
Treadles for single-line railway, 351.
Trewby, A., B.A., admitted student, 156.
Tunnel, Cornallaz, Chexbres (Switzerland), fall of the roof of the, 346.
Turbine, steam, tests of, at Hartford, Conn., 423.
Tylvad, J. J., manufacture of peat charcoal, 369.

Upcott, F. R.—*Discussion on the Nile Reservoir and Sluices:* Questions as to the results of tests of the lime and clay mortar, 132.

Vehicles, motor. See Automobiles.
———, working-costs of various methods of propulsion for, 38 *et seq.*
Vernon-Harcourt, L. F.—*Discussion on Nile Reservoir and Sluices:* Unique character of the dam, 128; the various designs for the dam, 129; silt in the Nile water, 131; disadvantages of reducing the height of the dam, 131; desirability of seeking further sources of supply for summer irrigation, 131; relative advantages of the Albert Nyanza and Lake Tsana in Abyssinia, 132.
———,—"*Düsseldorf Navigation Congress*, 1902; *and Works visited by the Congress in Germany*" (S.), 196.
Viaducts.—"*Erection of the Nairne Viaducts, near Adelaide, Australia*" (S.), 185.
Vibration, use of asphalt for the absorption of, 265.
Vogt, H. C., pendulum-propeller trials, 372.

Walker, C. T., B.Sc., elected associate member, 2.
Walzel, O., lock-and-block signalling with no releasing key, 355.
Water-power. See Electric power-transmission and Electricity stations.
——— purification, further experiments with ozone for, 375.
——— supply.—"*Burraga Dam and Water-Supply for the Lloyd Copper Company's Mine, New South Wales*," J. H. Cardew (S.), 237.—Catchment-area, 238; rainfall, 238; capacity of reservoir, 238; yield of gathering-ground, 238; trial pits, 239; design of dam for the impounding-reservoir, 241; construction, 243; stopping a leak, 245; pipe-line, 247; cost, 248.
——— tank with hemispherical bottom at Washington Heights, Chicago, 376.
———-works, Hamburg, 375.
Watt, J., elected associate member, 2.
Wells, L. B.—*Correspondence on the Nile Reservoir and Sluices:* Question as to area of land benefited by the construction of the dam, 149; use of sand for forming temporary dams in the River Weaver, 150; the Dutton sluices, 150; liability to deposition of mud in the locks, 151.
Weston, C. F. R. N., elected associate member, 156.
Willcocks, J., elected member, 2.

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Williams, C. J. R., transferred member, 1.
———, H. C., B.A., admitted student, 156.
Willmot, J. W., elected member, 156.
Wilson, C. S., admitted student, 1.
———, D., B.E., elected associate member, 156.
———, E., alternate-current electrolysis, 396.
———, J. M., memoir of, 332.
———, J. S., elected associate member, 156.
Winbolt, J. S., memoir of, 336.
Windsor, D. H., elected associate member, 156.
Winstanley, G., transferred member, 1.
Wood, E. S., elected member, 2.

Zschokke, B., the plasticity of clays, 386.

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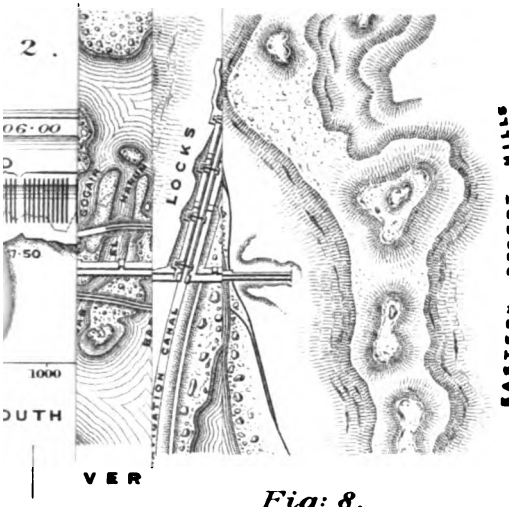
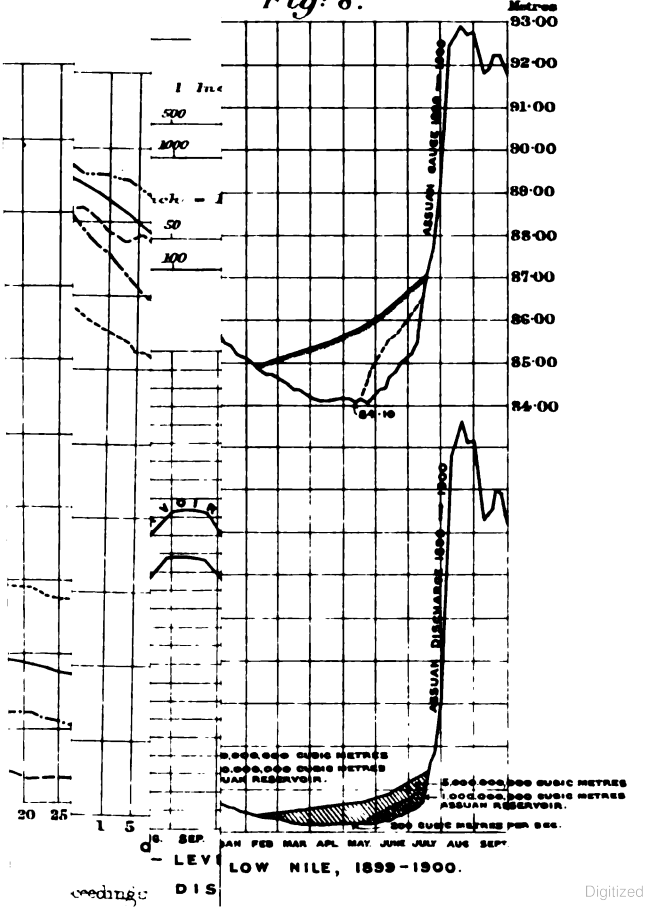


Fig: 8.



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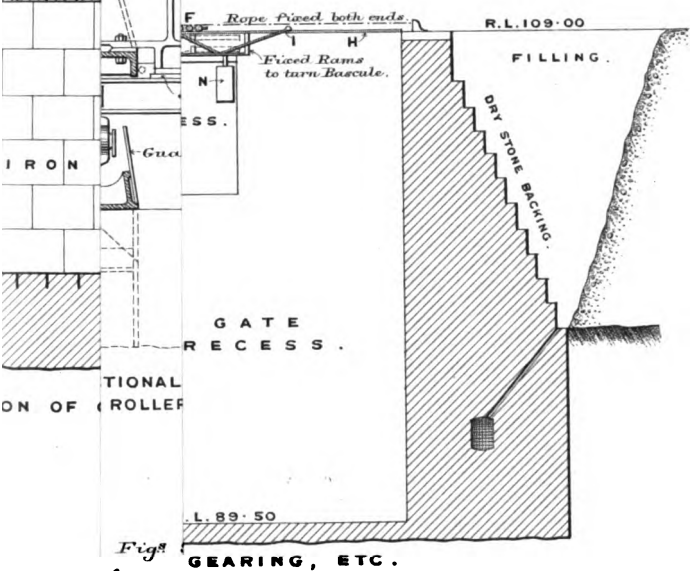
I Supply-pipe from Accumulators.
J ¾" Walking supply pipe to Travelling Rams.
K Fixed Rams to turn Bascule.
L Position of Bascule raised.
M Roller frame hinged at centre to turn up with the Bascule.
N Counterbalance Weight in Recess.



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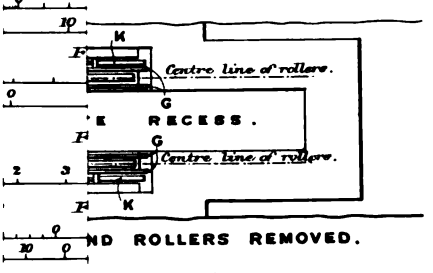

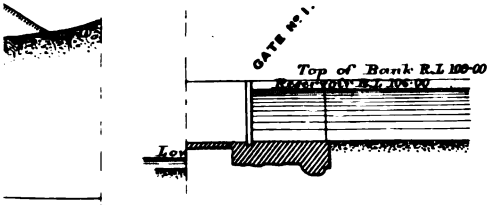

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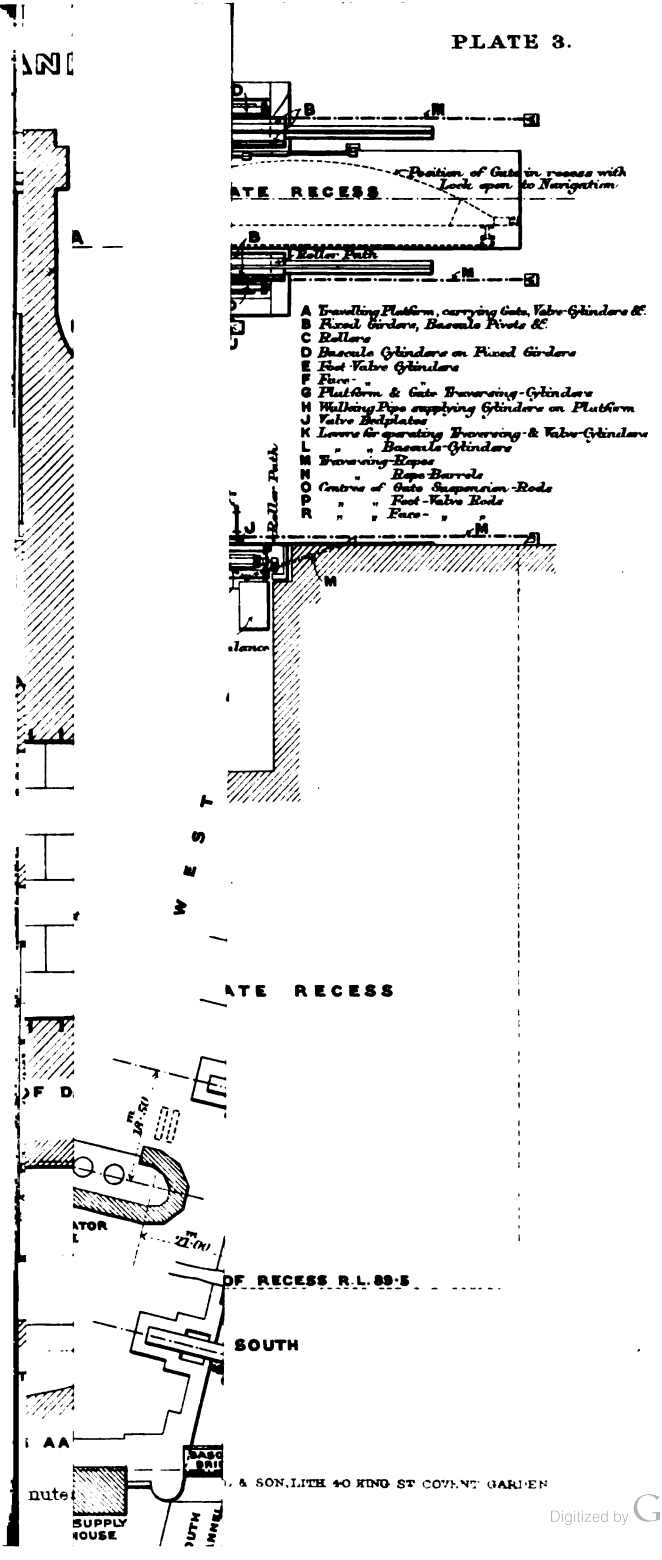
PLATE 3.

Position of Gate in recess with Lock open to Navigation
Roller Path
A Travelling Platform, carrying Gate, Valve-Grinders &c.
B Fixed Girders, Bascule Pivots &c.
C Rollers
D Bascule Grinders on Fixed Girders
E Foot Valve Grinders
F Face - " "
G Platform & Gate Traversing-Grinders
H Walking Pipe supplying Grinders on Platform
J Valve Endplates
K Levers for operating Traversing & Valve-Grinders
L " " Bascule-Grinders
M Traversing-Ropes
N " Rope-Barrels
O Centres of Gate Suspension-Rods
P " " Foot-Valve Rods
R " " Face- " "



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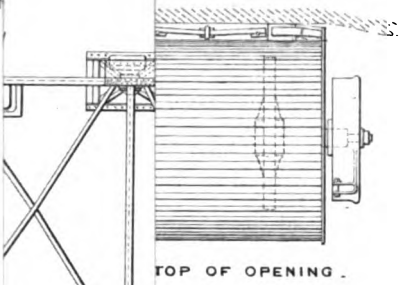

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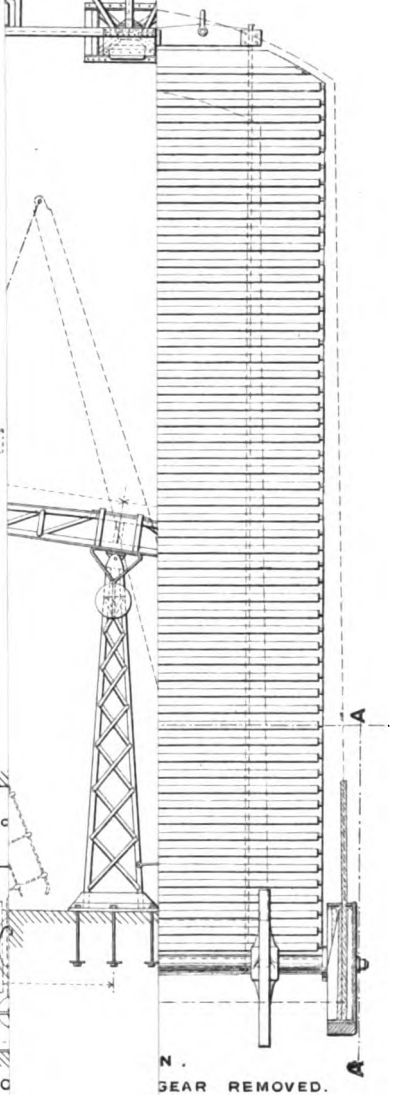

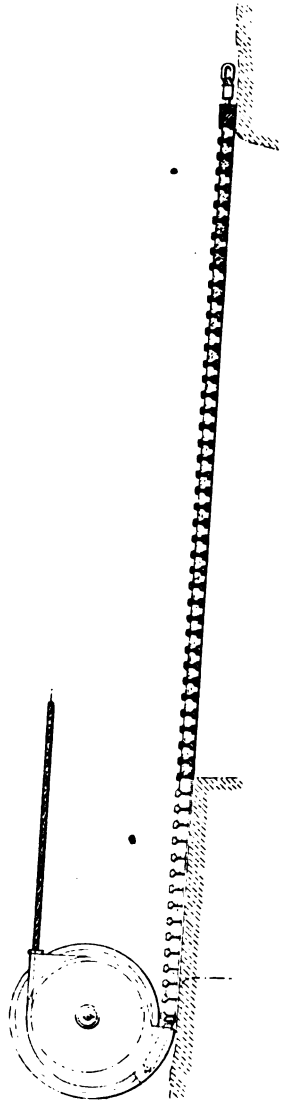

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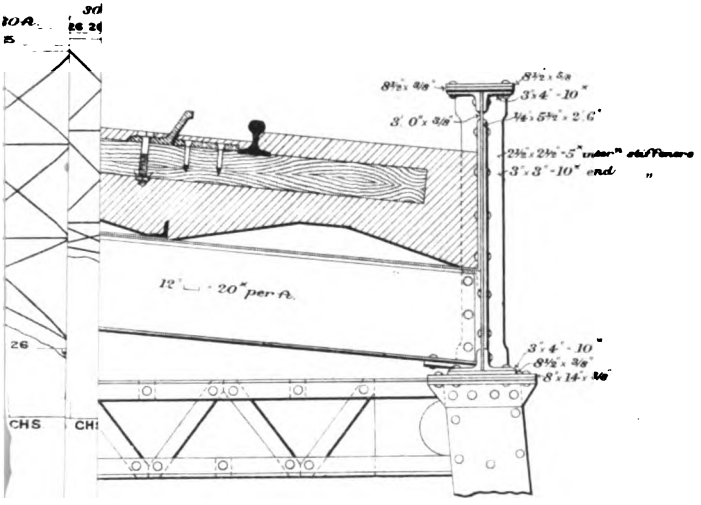
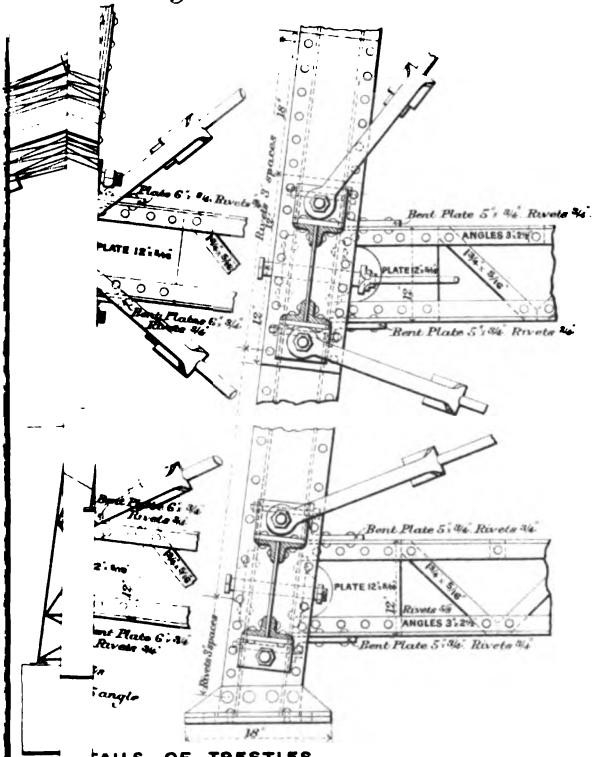


Figs. 3.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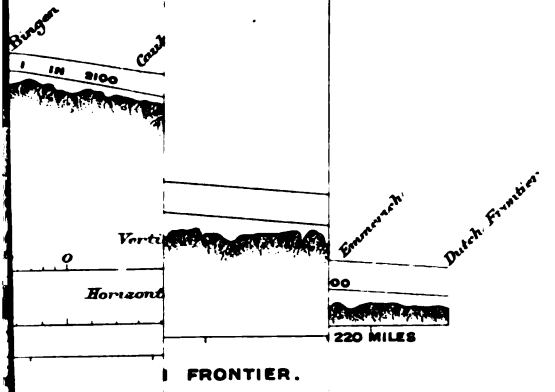

FRONTIER.

Fig: 2.

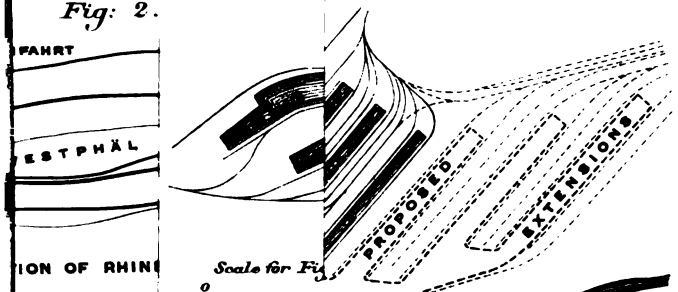

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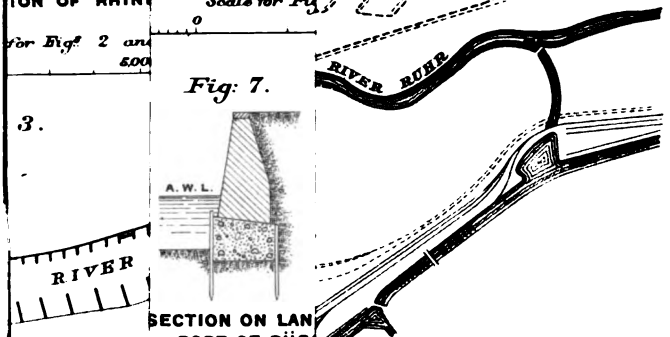
Fig: 7.

3.



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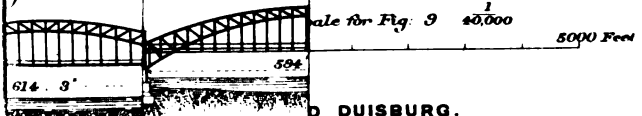

ale for Fig: 9 1/40,000

5000 Feet

IDGE AT BON ORF.

D DUISBURG.

L & SON, LITH. 40 KING ST COVENT GARDEN

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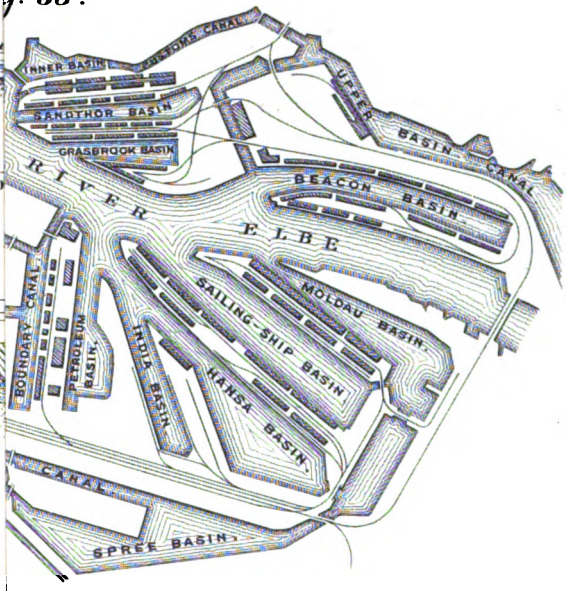
Fig: 38.

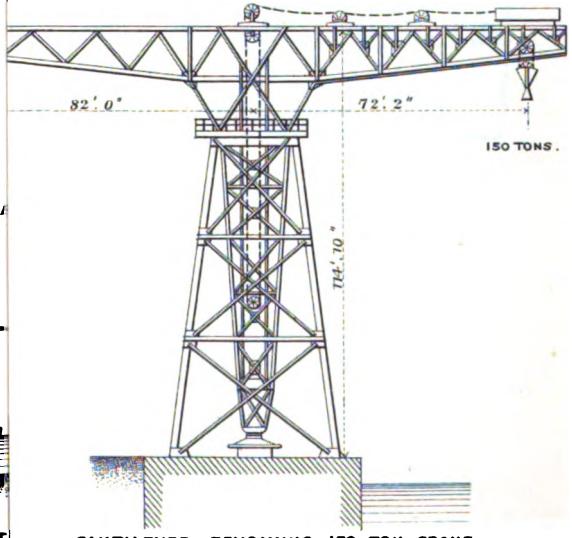


AMBURG IN 1902.

Fig: 38 ... 1/40,000.

5000 Feet.

Fig: 40.



CANTILEVER REVOLVING 150-TON CRANE.

Scale for Fig: 40 ..... 1/600.

Feet 10 5 0 10 20 30 40 60 100 Feet.

THOS HELL & SON, LITH. 40 KING ST. COVENT GARDEN.

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